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ИЗВЕСТИЯ

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

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RESEARCH OF THE USED METHYL ESTER OF VEGETABLE OIL AND ITS MIXTURES WITH DIESEL FUEL AS A FUEL IN COMPRESSION IGNITION ENGINE

Abstract. In this work researches of the used methyl ester of vegetable oil and their mixes with diesel fuel in various proportions as fuel for the purpose of studying of performance data of the engine and content of emissions were carried out. Biodiesel fuel was produced by transesterification in the presence of the catalyst of sodium hydroxide (NaOH) and potassium hydroxide (KOH) in proportions of 20% and 100% (on volume) which usually are called B20N, B100N, B20K, B100K, respectively.

The experiment was performed in the load range of 0%, 25%, 50%, 75% and 100%. It has been established that, compared with diesel fuel, when testing obtained biodiesel, CO emissions are reduced by 13.63%, 32.2% for mixtures of B20N and B100N at full load and by 4.5%, 32% for B20K and B100K, respectively. Compared to diesel fuel, biodiesel fuel and its mixtures showed a significant reduction in emissions of CO, hydrocarbons, smoke and particulate matter. However, the content of nitrogen oxides in used vegetable oil biodiesel was slightly higher than that of diesel fuel. The authors of the work conclude that the diesel engine can operate satisfactorily on biodiesel fuel and its mixtures with diesel fuel without any engine modifications.

Key words: biodiesel, transesterification, emission reduction, used vegetable oil, nitrogen oxides, diesel engine.

Introduction. In the era of global warming where the people are making their living more and more comfortable and they are deteriorating the environment also [1-3]. The world is on brink of energy crisis. The limited fossil fuel sources are increasing demand of energy [4, 5]. This associated with increasing cost of fossil fuels and the consciousness of the impacts of environmental pollution has forced a search for an alternative source of energy, which is renewable, harmless and non-polluting [6, 7]. When it comes to world, energy consumption which is drastically increased for last decade. People still depends mostly on fossil fuels to fuel their vehicles, in spite of the environment problem that flow from burning coal oil and natural gas [8, 9]. So many research works are carried out in many nations like India to search an appropriate fuel source such as solar and the wind as the great alternatives which are neat copious and on the edge of mass production in the upcoming days that always seems around the corner yet eternally out of reach [10, 11]. Nowadays, renewable energy sources of the world's supply, fossil fuels provide about 85% technologically higher which have damped the cost of renewable power sources, but technology has also kept down the price using fossil fuels and some cases reduced their unsafe effects on the environment [12, 13].

The vegetable oils gratify the major necessities for a diesel engine fuel, their suitability as alternative to diesel fuel have been consider as a topic of research. Under the biofuels generally understand the liquid fraction of vegetable origin, intended for additive in petroleum fuels or for direct use in the engine. For example, ethyl alcohol obtained from agricultural raw materials, as an energy carrier, is no different from

hydrolytic or synthetic ethanol, but its producers and consumers, for example, in the European Union countries have great preferences. This is due to the desire not only to solve the problem of expanding the fuel base, but also to stimulate its own agricultural producer. An important advantage of biofuels is the replacement of refined products with natural renewable raw materials. Therefore, the greatest attention is paid to this problem in countries poor in oil but possessing rich plant resources [14, 15]. To biofuels include ethanol, obtained by fermentation of plant materials (bioethanol), ethers, for the production of which bioethanol and methyl esters of fatty acids obtained from vegetable oils were used. According to the definition of the US standard, biodiesel fuel is understood to mean monoalkyl esters of fatty acids derived from vegetable or animal oils and intended for use in diesel engines. The main task that is being solved at the same time is the replacement of refined products with natural renewable resources [16, 17].

Thus, the rapid consolidation of biofuel positions is due to the desire to support the agricultural producer.

Compression ignition (CI) engines are more far and wide used compared to spark ignition (SI), greater thought is being committed to expand an alternative source of fuel for the CI engine. When vegetable oils are charged in a CI engine, the safety of a CI engine should be considered as a major factor. Vegetable oils and their suitability to diesel fuel as an alternative were considered as a subject of the research in [18, 19].

Biodiesel plants are not capital-intensive plants [20-23]. The majority of the cost is expended for production of biodiesel from the oil. The cost associated with catalysts such as KOH or NaOH and neutralizing acid is not important. On the other hand, there are so many indirect benefits that are possible in India. For example, in India considerable waste land is available. The energy farming by cultivation of oil bearing plants can generate employment in tree plantations; seed picking, in oil mills where extraction is carried out and then the biodiesel plant itself [24-26].

The problem of increasing demand of fuel, engine performance and emissions characteristics are greater threat to the field of automobiles. The hike in fuel cost has caused many to re-evaluate alternative fuel that has huge potential globally [27]. On the other hand, the application of used vegetable oil methyl ester in diesel engines brings into focus the various challenges that might be faced by public usage [28-30].

In a country like India, where agriculture is the main profession and kirloskar engine are mostly used by the farmers for various applications like water pumping the main problems are the increasing demand of fuel, cost and emission [31, 32]. The biodiesel is considered as an alternate fuel for diesel engines especially, during the periods of diesel scarcity.

The main aim of this research is to demonstrate how capably an engine can be run by applying used vegetable oil methyl ester (biodiesel) and its blends when compared to diesel.

The objectives of this work are to investigate the engine performance on emission of Used Vegetable Oil Methyl Ester (UVOME) which is derived through transesterification process by using the Bio-diesel Processor. The two different catalysts (KOH and NaOH) are investigated to find the emission reduction and recycling of UVOME. The biodiesel and its blends are studied and compared with diesel.

Materials and methods. Experimental tests have been performed at the single-cylinder, four-cycle, naturally aspirated and water-cooled test bench with the diesel Kirloskar engine. The diesel engine was directly connected with a vortex-current dynamometer. The engine and a dynamometer were connected to the control panel which was connected to the computer. This computerized test bench was used for reading of parameters of tests. Installation is supplied with necessary devices for measurement of pressure of combustion and an angle of rotation of a bent shaft. These signals are connected with the computer via the engine indicator for charts of pQ-pV.

All the tests were carried out when the engine was operated on UVOME, and their mixtures were obtained through a transesterification process using a catalyst (sodium hydroxide (NaOH) and potassium hydroxide (KOH)) in proportions of 20% and 100% (vol.), they are usually called B20N, B100N, B20K, B100K respectively.

Samples of biodiesel were prepared according to the scheme shown in figure 1. Methanol (molar ratio 1:3 oil:alcohol) was mixed with NaOH/KOH (1 wt.% of oil), slowly added to the reactor containing oil when mixing. Reactionary mixture is boiled with the return refrigerator within 2–4 hours. By means of TLC the completeness of reaction was checked. After the end of a reaction the produced compound was

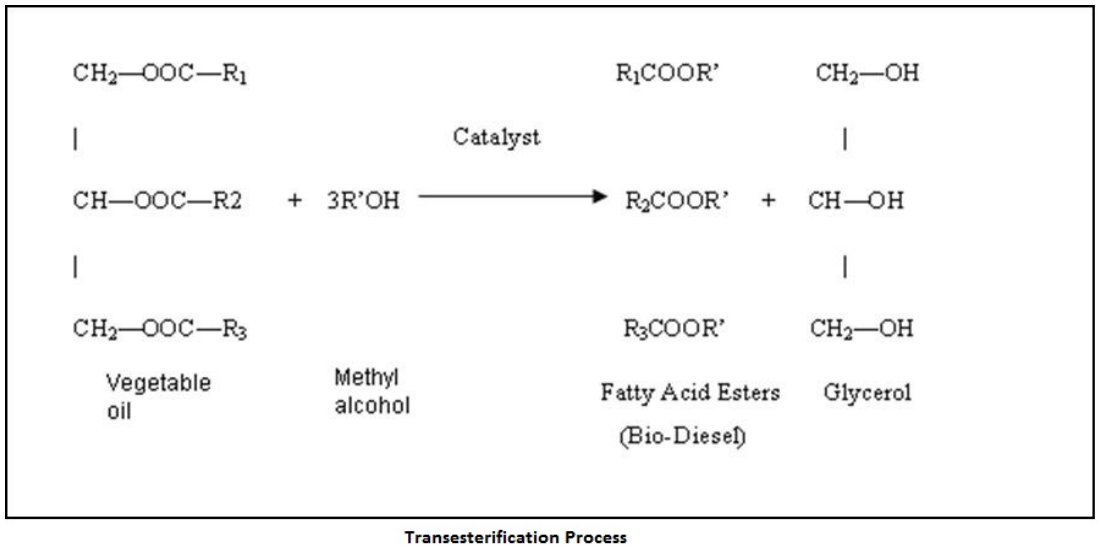

Figure 1 – A scheme of an alkali catalyzed method

transferred to a dividing funnel and both phases were divided. The top phase represented the biodiesel, and the lower part was glycerin. Alcohol from both phases was driven away in a vacuum. The glyceric phase was neutralized by acid and stored in a type of the crude glycerin. The top phase, that is methyl air (biodiesel fuel), was washed with water for removal of traces of glycerin, not reacted catalyst and soap formed during transesterification twice. Residual product was kept in a vacuum to get rid of residual moisture. Table shows properties of various mixes produced in the course of transesterification.

In this research data for loadings of 0%, 25%, 50%, 75% and 100% were obtained.

Properties of Various Blends

Fuel	Fuel Density (kg/m^3)	Calorific Value (kJ/kg)
Diesel	830	42,000
B20N	886	40,919
B100N	918	37,292
B20K	884	41,392
B100K	914	37,848

Results and discussion. In figure 2 are shown data of experiments for determination of CO emissions for diesel fuel, BN and its blends, BK and its blends at different load conditions. Obviously that CO emissions are significantly decreased in the case of introduction of BN or BK to diesel fuel. It was found that CO emission reduced from 13.6 to 32.37% for BN blends. The emission of CO reduced from 4.54 to 32% in the case of BK blends at full load condition. In this research experiments show that CO concentration in the case of biodiesel and blends is lesser for BN blends by comparison with the other fuels. BK blends demonstrated reduced CO emission than diesel.

Probably it can be because the oxygen content in biodiesel allowing more carbon molecules to be oxidized when compared with the diesel fuel.

Data on the unburnt hydrocarbon emissions for BK blends and BN blends in comparison with diesel are shown in figure 3. It was found that hydrocarbon emissions are decreased at any chosen load for BN and BK blends. The lowest content of hydrocarbons (25 ppm) is revealed for B100K, it was least than for all other examined fuels. Compared to BK fuel blends, the emission of HC is slightly on higher side in BN fuel blends. The causes of the reduction of hydrocarbon emission may be deeper combustion because of the increased oxygen content in the flame forming from the biodiesel molecules.

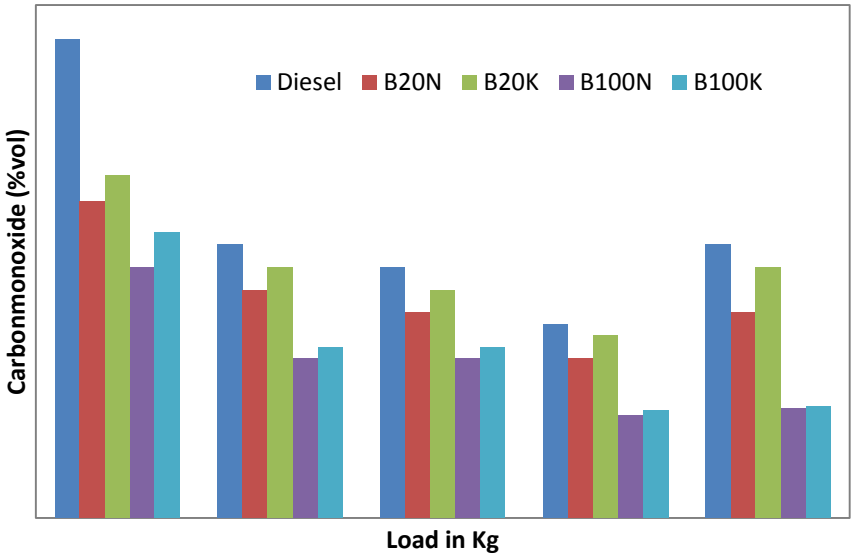

Figure 2 – Data of CO emissions for diesel, BN and BK at the different load conditions

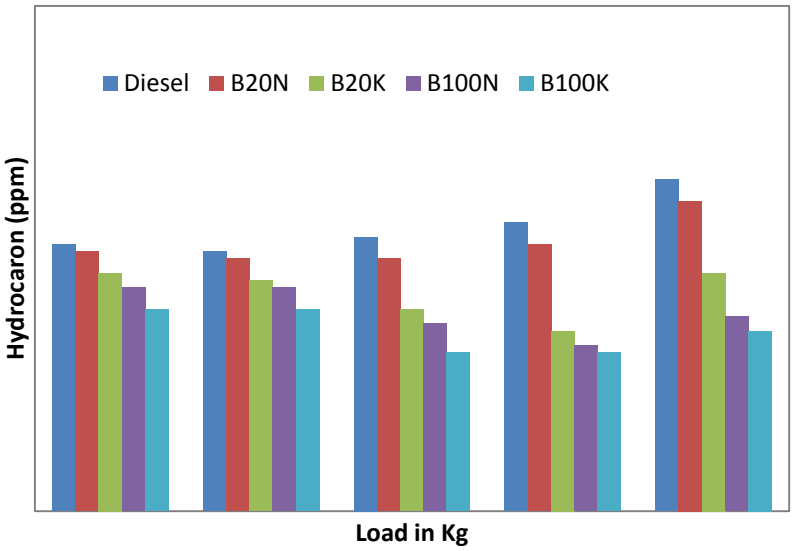

Figure 3 – Data of hydrocarbons emissions for diesel, BN and BK at the different load conditions

Data on determination of content of NO_x for diesel fuel, BN and its mixes, BK and its mixes under various conditions of loading are shown in figure 4. It is revealed that emissions of nitrogen oxides increase at addition of BN, BK in comparison with diesel fuel a little. Formation of NO_x in a cylinder of the engine is influenced by the oxygen content, temperature of burning of a flame and duration of oxidation. Formation of NO_x in all biodiesels and mixes is a little more, than in diesel fuel, and the maintenance of NOx in B100K is 18% higher, than in usual diesel fuel in the conditions of full load.

Increasing particulate matter content happened because of non-deep burning. It was found that content of PM emissions was higher for diesel fuel than for all other biodiesel blends of BN and BK. The figure 5 shows the data on particulate matter for diesel, BN and BK at different load conditions. When the blends are increased in %, the content of PM is decreased. The lowest particulate emission (0.731 g/min) was detected in the case of B100N blend. When use BN the content of PM was lesser than for BK blends.

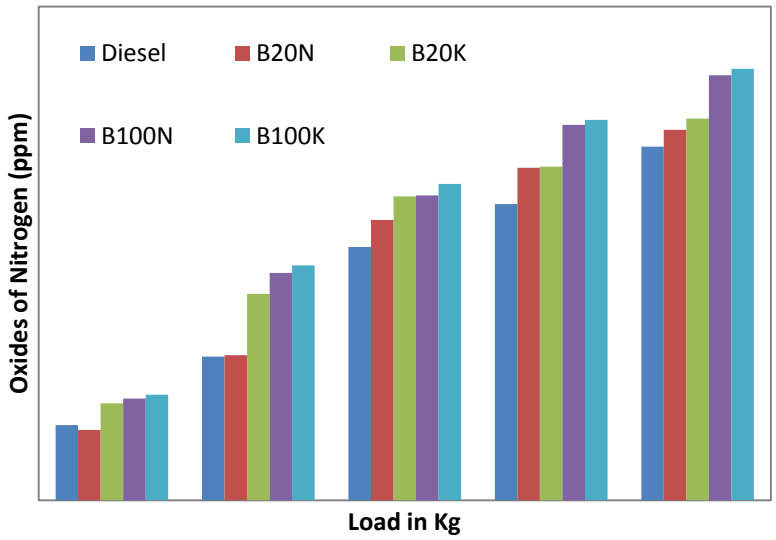

Figure 4 – NO_x emissions for diesel, BN and BK at different load conditions

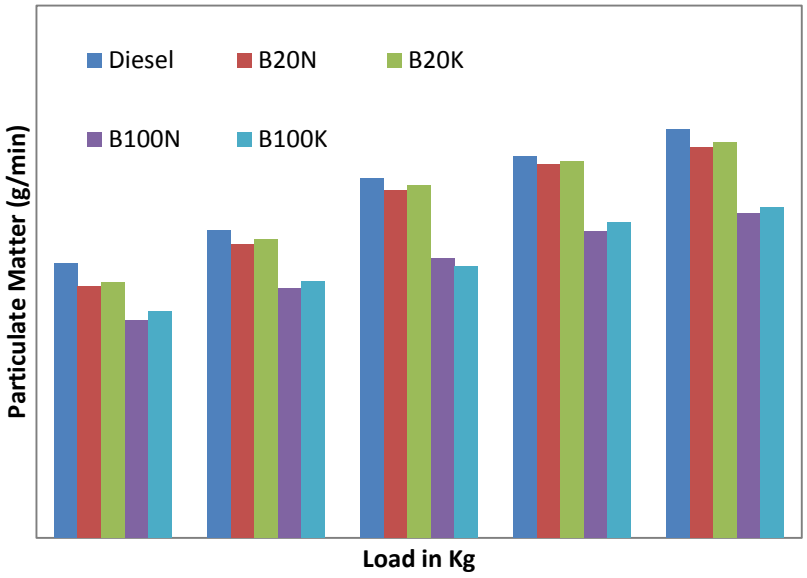

Figure 5 – Data on particulate matter for diesel, BN and BK at different load conditions

The smoke opacity of all the fuels used in this research is shown in figure 6. It was found that the smoke contents of biodiesel and its 20% blends are higher than that of diesel fuel at low and middle engine loads. Possibly, it is connected with high viscosity of the biodiesel that leads to bad dispersion and locally saturated mixes during the work with partial loading. But at high load of the engine density of smoke of all mixes of the biodiesel is lower, than at diesel fuel. It is connected with oxygen content in the biodiesel in comparison with the conventional diesel fuel.

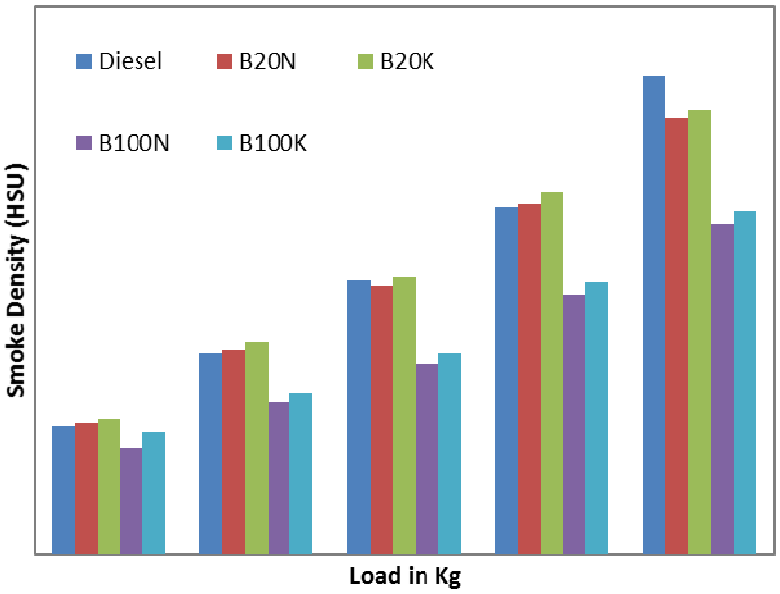

Figure 6 – Data on smoke density for diesel, BN and BK at different load conditions

Conclusions. In the work the used cooking oil methyl esters produced using KOH and NaOH, and their blends were tested as fuel and the results were compared with the emission characteristics in the case of diesel fuel.

It was found that the heating value of B20K is very close to a heating value of the diesel and the diesel engine can well work on the tested biodiesel and its mixtures with diesel fuel without any modifications of the engine. Experiments demonstrated high degree of decreasing emissions of carbon monoxide, hydrocarbons, smoke and particulate matter when apply biodiesel and its mixtures in comparison with diesel fuel. BK blends shows reduced CO emission than diesel. The lowest value of hydrocarbon emission is obtained for B100K is 25 ppm than all other fuels such as diesel, BN blends. When the blends are increased in percentage, the particulate matter is reduced. The lowest particulate emission of 0.731 g/min obtained from B100N blend. BN shows lesser particulate matter than BK blends. However the NO_x content when using the used cooking vegetable oil - biodiesel is insignificant above, than in the case of diesel fuel. We can conclude that the used methyl vegetable oil (UVOME) can successfully replace a diesel fuel for reduction air pollution.

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ПАЙДАЛАНЫЛҒАН МЕТИЛ ЭФИРІНІҢ ӨСІМДІК МАЙЫН ЖӘНЕ ОНЫҢ ДИЗЕЛЬДІ ОТЫНМЕН ҚОСПАЛАРЫН ҚОЗҒАЛТҚЫШТА ЖАҒУДЫ ЗЕРТТЕУ

Аннотация. Зерттеу барысында қозғалтқыштың өнімділігі мен шығарындыларын зерттеу үшін өсімдік майының қалдықтарының метил эфирін және дизельді отынның қоспаларын жанармай ретінде түрлі пропорцияларда зерттеу жүргізілді. Биодизельді отын, тиісінше, B20N, B100N, B20K, B100K деп аталатын 20 және 100% (көлемі бойынша) пропорцияда натрий гидроксидінің (NaOH) және калий гидроксидінің (KOH)

катализаторы болған кезде переэтерификация арқылы алынған. Тәжірибе 0%, 25%, 50%, 75% және 100% жүктеме ауқымында жүргізілді. Дизельді отынмен салыстырғанда, алынған биодизельді сынақтан өткізген кезде CO шығарындылары 13,63%-ға, B20N және B100N қоспаларының толық жүктемесінде 32,2%, B20K және B100K үшін 4,5%, 32%-ға төмендегені анықталды. Дизельді отынмен, биодизельдік отынмен және оның қоспаларымен салыстырғанда CO, көмірсутектер, түтін және қатты заттар шығарындыларының айтарлықтай төмендеуі байқалды. Дегенмен, азот оксидтерінің құрамында өсімдік майы биодизелі дизельді отынға қарағанда біршама жоғары болды. Жұмыстың авторлары дизель қозғалтқышы биодизель отынына және дизельдік отынмен қоспаларына қозғалтқышты модификациялаусыз қанағаттанарлық жұмыс істей алады деп тұжырымдайды.

Түйін сөздер: биодизель, қайта этерификациялау, өсімдік майы, азот тотығы, дизельді қозғалтқыш.

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ИССЛЕДОВАНИЕ ОТРАБОТАННОГО МЕТИЛОВОГО ЭФИРА РАСТИТЕЛЬНОГО МАСЛА И ЕГО СМЕСИ С ДИЗЕЛЬНЫМ ТОПЛИВОМ В КАЧЕСТВЕ ТОПЛИВА В ДВИГАТЕЛЕ КОМПРЕССИОННОГО ЗАЖИГАНИЯ

Аннотация. В работе проводились исследования отработанного метилового эфира растительного масла и их смесей с дизельным топливом в различных пропорциях в качестве топлива с целью изучения рабочих характеристик двигателя и содержания выбросов. Биодизельное топливо было получено путем трансэтерификации в присутствии катализатора гидроксида натрия (NaOH) и гидроксида калия (KOH) в пропорциях 20 и 100% (по объему), которые обычно называются B20N, B100N, B20K, B100K, соответственно. Эксперимент проводился в диапазоне нагрузок 0%, 25%, 50%, 75% и 100%. Установлено, что, по сравнению с дизельным топливом, при испытании полученного биодизеля выбросы CO снижаются на 13,63%, 32,2% для смесей B20N и B100N при полной нагрузке и на 4,5%, 32% для B20K и B100K, соответственно. По сравнению с дизельным топливом, для биодизельного топлива и его смесей выявлено значительное снижение выбросов CO, углеводородов, дыма и твердых частиц. Однако, содержание оксидов азота в отработанном растительном масле биодизеля было незначительно выше, чем у дизельного топлива. Авторы работы делают вывод, что дизельный двигатель может удовлетворительно работать на биодизельном топливе и его смесях с дизельным топливом без каких-либо модификаций двигателя.

Ключевые слова: биодизель, трансэтерификация, снижение выбросов, отработанное растительное масло, оксиды азота, дизельный двигатель

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REFERENCES

[1] Meinshausen M., Meinshausen N., Hare W., Raper S.C.B., Frieler K., Knutti R., Frame D.J., Allen M.R. (2009). Greenhouse-gas emission targets for limiting global warming to 2 °C // Nature. 458: 1158-1163 (in Eng.).

[2] Sassykova L.R. (2018). Technogenic emissions into the atmosphere: impact on the environment and neutralization by catalytic methods. Almaty: Qazaq university. ISBN 978-601-04-3440-0 (in Eng.).

[3] McGrath M. (2017). Four major cities move to ban diesel vehicles by 2025. http://www.bbc.com/news/science-environment-38170794 (in Eng.).

[4] Bilgen S. (2014). Structure and environmental impact of global energy consumption // Renew. Sustain. Energy Rev. 38: 890-902 (in Eng.).

[5] Aubakirov Y.A., Sassykova L.R., Nalibayeva A.M., Dossumov K., Tashmukhambetova Z.K., Zhumakanova A.S., Zhussupova A.K., Zhakirova N.K. (2017.) Synthesis and testing of catalysts for decrease of toxic emissions of vehicles // Oriental Journal of Chemistry. 33(6): 3130-3137 (in Eng.).

[6] Val'dberg A.Yu., Kosogorova T.O., Tsedilin A.N., Pokrovskii D.D., Yakimychev A.A. (2007). Cleaning diesel plant exhaust gases // J. Chem. and Petrol. Eng, 5-6: 287-291. http://dx.doi.org/10.1007/s10556-007-0051-7 (in Eng.).

[7] Burdeinaya T.N., Matyshak V.A., Tret'yakov V.F., Glebov L.S., Zakirova A.G., Garcia Carvajal M.A., Villanueva Arias M.E. (2007). Design of catalysts for deNOx process using synergistic phenomenon // Applied Catalysis B: Environmental. 1-4: 128 (in Eng.).

[8] Takami A., Ichikawa T. (1995). Catalyst for purification of exhaust gases // J. Zeolites. 15: 283 (in Eng.).

[9] Sassykova L., Bunin V., Nalibayeva A., Nurakhmetova M. (2018). Synthesis of catalysts on the metal block carriers and testing their effectiveness in the real conditions of operation // J. Chem. Technol. Metall. 53: 537-542 (in Eng.).

[10] Sassykova L., Gil'mundinov Sh., Nalibayeva A., Bogdanova I. (2017). Catalytic systems on metal block carriers for neutralization of exhaust gases of motor transport // Rev. Roum. Chim. 2: 107-114 (in Eng.).

[11] Baiseitov D.A., Tulepov M.I., Sassykova L.R., Kudaibergenov K.K., Mansurov Z.A. (2015.) The sorbents for collection of oil and petroleum of the phytogenesis // Int J Chem Sci. 13: 1027–33.

[12] Talebian-Kiakalaieh A., Amin N.A.S., Mazaheri H. (2013). A review on novel processes of biodiesel production from waste cooking oil // Appl Energy. 104: 683-710. doi:10.1016/j.apenergy.2012.11.061 (in Eng.).

[13] Sendilvelan S., Bhaskar K. (2017). Comparative performance studies on DI diesel engine with neem de-oiled cake and Jatropha methyl ester diesel blends // World J Eng. 14: 348-52. doi:10.1108/WJE-09-2016-0072 (in Eng.).

[14] Kagawa S., Takezono K., Suh S., Kudoh Y. (2013). Production possibility frontier analysis of biodiesel from waste cooking oil // Energy Policy. 55: 362–8. doi:10.1016/j.enpol.2012.12.016 (in Eng.).

[15] Ullah Z., Bustam M.A., Man Z. (2015). Biodiesel production from waste cooking oil by acidic ionic liquid as a catalyst // Renew Energy. 77: 521-6. doi:10.1016/j.renene.2014.12.040 (in Eng.).

[16] Hossain A.B.M.S., Boyce A.N. (2009). Biodiesel production from waste sunflower cooking oil as an environmental recycling process and renewable energy // Bulg J Agric Sci. 15: 312-7. doi:10.9734/BBJ/2016/22338 (in Eng.).

[17] Zhang Y., Dubé M., McLean D., Kates M. (2003). Biodiesel production from waste cooking oil: 2.Economic assessment and sensitivity analysis // Bioresour Technol. 90: 229-40. doi:10.1016/S0960-8524(03)00150-0 (in Eng.).

[18] Bilgin A., Gülüm M., Koyuncuoglu İ., Nac E., Cakmak A. (2015). Determination of transesterification reaction parameters giving the lowest viscosity waste cooking oil biodiesel // Procedia - Soc Behav Sci. 195: 2492-500. doi:10.1016/j.sbspro.2015.06.318 (in Eng.).

[19] Panadare D.C., Rathod V.K. (2015). Applications of waste cooking oil other than biodiesel: A Review // Iran J Chem Eng. 12: 55-76 (in Eng.).

[20] Sendilvelan S., Bhaskar K. (2017). Aluminium phosphate supported copper phosphate catalytic converter to reduce nitrous oxides and particulate matter from engine emission // Oriental J Chem. 33: 2111-2117 (in Eng.).

[21] Sendilvelan S., Bhaskar K. (2017). Chemical and experimental analysis of fumigation process to reduce emission without affecting the performance of an engine // Rasayan Journal of Chemistry. 10: 111-116 (in Eng.).

[22] Tungatarova S.A., Xanthopoulou G., Kaumenova G.N., Zhumabek M., Baizhumanova T.S., Grigorieva V.P., Komashko L.V., Begimova G.U. (2018). Development of composite materials by combustion synthesis method for catalytic reforming of methane to synthesis gas // News of the National Academy of sciences of the Republic of Kazakhstan. Series of chemistry and technology. 432: 6-15. https://doi.org/10.32014/2018.2518-1491.20 (in Eng.).

[23] Mohammadshirazi A., Akram A., Rafiee S., Bagheri Kalhor E. (2014). Energy and cost analyses of biodiesel production from waste cooking oil // Renew Sustain Energy Rev. 33: 44-9. doi:10.1016/j.rser.2014.01.067 (in Eng.).

[24] Yaakob Z., Mohammad M., Alherbawi M., Alam Z., Sopian K. (2013). Overview of the production of biodiesel from Waste cooking oil // Renew Sustain Energy Rev. 18: 184-93. doi:10.1016/j.rser.2012.10.016 (in Eng.).

[25] Enweremadu C.C., Mbarawa M.M. (2009). Technical aspects of production and analysis of biodiesel from used cooking oil-A review // Renew Sustain Energy Rev. 13: 2205-24. doi:10.1016/j.rser.2009.06.007 (in Eng.).

[26] Lin B.F., Huang J.H., Huang D.Y. (2009). Experimental study of the effects of vegetable oil methyl ester on DI diesel engine performance characteristics and pollutant emissions // Fuel. 88: 1779-85. doi:10.1016/j.fuel.2009.04.006 (in Eng.).

[27] Sun J., Caton J.A., Jacobs T.J. (2010). Oxides of nitrogen emissions from biodiesel-fuelled diesel engines // Prog. Energy Combust. Sci. 36: 677-95. doi:10.1016/j.pecs.2010.02.004 (in Eng.).

[28] Johann Dueck J., Tatayeva R., Baymanova A., Bakeshova Z., Kapsalyamov B. (2018). Biological treatment of waste water:theoretical background and experimental research // News of the National Academy of sciences of the Republic of Kazakhstan. Series of Chemistry and Technology. 432: 16-22. https://doi.org/10.32014/2018.2518-1491.21 (in Eng.).

[29] Ng J.H., Ng H.K., Gan S. (2010). Advances in biodiesel fuel for application in compression ignition engines // Clean Technol. Environ. Policy. 12: 459-93. doi:10.1007/s10098-009-0268-6 (in Eng.).

[30] Valente O.S., Da Silva M.J., Pasa V.M.D., Belchior C.R.P., Sodré J.R. (2010). Fuel consumption and emissions from a diesel power generator fuelled with castor oil and soybean biodiesel // Fuel. 89: 3637-42. doi:10.1016/j.fuel.2010.07.041 (in Eng.).

[31] Prabhahar M., Sendilvelan S., Sassykova L.R. (2018). Studies on pongamia oil methyl ester fueled direct injection diesel engine to reduce harmful emissions // Indian J. Environmental Protection. 38: 269-277 (in Eng.).

[32] Bhaskar K., Sassykova L.R., Prabhahar M., Sendilvelan S. (2018). Effect of dimethoxy-methane ($C_3H_8O_2$) additive on emission characteristics of a diesel engine fueled with biodiesel // International Journal of Mechanical and Production Engineering Research and Development. 8: 399-406 (in Eng.).

[33] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

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DIGITALIZATION OF HYDROGEOLOGICAL SURVEYS RESULTS IN ArcGIS

Abstract. Modernization of the state system of geodesic support and creating the maps in a single coordinate system and according to uniform data structures are required to digitize, unify, develop and maintain the integrity of spatial data [1]. A scientific and methodological basis for structurization of the hydrogeological maps using geoinformation systems is being developed, and a library of conventional signs of hydrogeological subject matter was created under the project No. AR05131239 [2]. Development of methodological approaches to solving the problem of unification of hydrogeological objects is important due to the lack of a unified methodology for drawing up digital hydrogeological maps in the Republic of Kazakhstan. Creation of a series of map sheets and use thereof when applying a software product ArcGIS with the same conventional signs is also relevant in other countries of Central Asia [3]. This article covers the stage of structurization of the "Hydrogeology" style of cartographic data within the ArcGIS environment.

Keywords: GIS, digitalization, hydrogeology, cartography, geodatabase, map.

Introduction. Modern geographic information system make it possible to convert any spatial objects, phenomena, processes of the real world into digital format, i.e. in the form of a digital map, and save information about them in a database.

The most illustrative form of representing the peculiarities of underground water (UW) distribution and formation are hydrogeological maps.

Hydrogeological maps characterize the distribution, conditions and occurrence depth, qualitative and quantitative components of UW, as well as thickness, filtration parameters of water-bearing and water-resistant formations shall be made based on the results of hydrogeological studies with the use of geological, geomorphological, hydrological and other information. Requirements to the geological maps are given on the website of the Committee for Geology and Subsoil Use, including in the Instruction for the making and preparation for publishing the sheets of the Republic of Kazakhstan state geological map with the scale of 1:200 000; methodological guideline for the compilation of series legends of the State GeolMap–200 [4]. Effective requirements to the making of hydrogeological maps are stated in the Instruction for the making and preparation for publishing of sheets of the state hydrogeological map of Kazakhstan with the scale of 1:200000 approved by the Order of the Committee for Geology and Subsoil Use of the Ministry of Energy and Mineral Resources of the Republic of Kazakhstan dated 09.11.2004 No. 143-п. [5] and also in Stratigraphic Code, SNiP RK 1.02-18-2004 and GOST 21.302-2013 [6]. Specialized publications devoted to hydrogeological databases (DB) and GIS give the main requirements to their architecture and provisioning. These include compliance with DB standardization rules - uniqueness of tables, avoidance of data redundancy and duplication. Unified requirements to hydrogeological maps must underlie the works of structuring the geodatabase and creation of a special style in ArcGIS.

Survey methods: system analysis, spatial analysis, GIS-technologies and geoinformation methods of displaying hydrogeological surveys; cartography integration.

Results. Hydrogeological maps reflect the results of hydrogeological surveys: state of groundwater, main types of rocks and water bodies, types of UW by hydraulic properties, interaction with surface waters, geochemical types of UW regime, as well as exogenous processes caused by UW activities [7].

These data should be laid on hydrogeological maps, taking into account the rules of their graphic design dictated by the specialized literature and GOSTs which are relevant for the Republic of Kazakhstan and neighbouring countries, and they can be conventionally combined into sets of classes. Each class in ArcGIS has its subtypes which in their turn are divided into domains [8].

1. Information about the set of classes of objects "Horizons and complexes (hydrogeological units)" shall include the following classes of objects:

- Horizons and complexes (polygons),
- Borders of various aquiferous complexes (lines).
- Borders of various degrees of mineralization aquiferous complexes (lines).
- Borders of UW chemical composition
- Isopachytes (thickness of aquiferous horizons)
- Isolines of depths of aquiferous horizons top
- Isolines of depths of aquiferous horizons bottom
- Horizons and complexes occurring above the first from surface persistent by area units (lines)
- Horizons and complexes occurring below the first from surface persistent by area units (lines)

2. Information about the set of classes of objects "Hydrodynamics" shall include the following classes of objects:

- Direction of ground water flow (lines)
- Hydroisohypses (lines)
- Hydroisopiestics (lines)
- Ground water pinchout (lines)
- Class of objects UW dividing range (lines)
- Groundwater recharge at account of infiltration and inflow of precipitations (lines)
- Groundwater recharge at account of infiltration and inflow of surface water (lines)
- Groundwater recharge through tectonic faults (dots)
- Sites of water vapor intense condensation and its value, mm/year (polygons)
- Groundwater discharge at account of plants transpiration (lines)
- Sites of UW discharge into lakes and rivers (lines)
- UW discharge areas (traverses)
- Borders of suberimposed depressions or saddles that are drainage systems of mineral or thermal water (lines)
- Borders of sites of UW intense evaporation (lines)
- Sites of hidden discharge (dots) (UW flow-over from one aquiferous object to another through lithological windows)
- Isolines of long-time annual average underground water runoff module (lines)
- Head intensity (lines)

3. Information about the set of object classes "Tectonics" includes the following object classes:

- Fractured zones (lines)
- Fractured zones (polygons)

4. Information about the set of classes of objects "Hydrogeological zoning" includes the following object classes:

- Hydrogeological zones (polygons)
- Hydrogeological zones (table)
- Borders of hydrogeological zones (lines)

5. Information about the set of object classes "Sections" includes the object class "Section lines".

6. Information about the set of object classes "Water points – natural and artificial water- and gas showings" includes the following object classes:

- Hydrogeological wells (dots)
- Groups of wells (dots)
- Well clusters (dots)
- Water-absorbing wells (dots)
- Springs object class (dots)
- Groups of springs (dots)
- Mines (dots)
- Shafts/pits (dots)
- Group capping of shafts/pits (dots)
- Dry gas jets (dots)

7. Information about the set of classes of objects "Fields, resources, UW use, intake structures" includes the following object classes:

- UW fields and resources (polygons)
- Water-supply wells (dots)
- Groups of water supply wells (dots)
- Karizes and water-intake galleries (radial wells) (dots)
- Mineral water use points (dots)

8. Information about the set of object classes "Indicators and processes having hydrogeological importance" includes the following object classes:

- Fresh water lenses (polygons)
- Fresh water lenses (dots)
- Leakage water sites (dots)
- Borders of flooded buried valleys (lines)
- Flooded alluvial cones (dots)
- Swelling hummocks of "mii" type (lines)
- Borders of permafrost rock (lines)
- Spots of permafrost rock (dots)
- Isolines of permafrost rock thickness (lines)
- Hydroisotherms (lines)

9. Information about the set of object classes "Numbering" includes the object class "Numbering by nomenclature (polygons)".

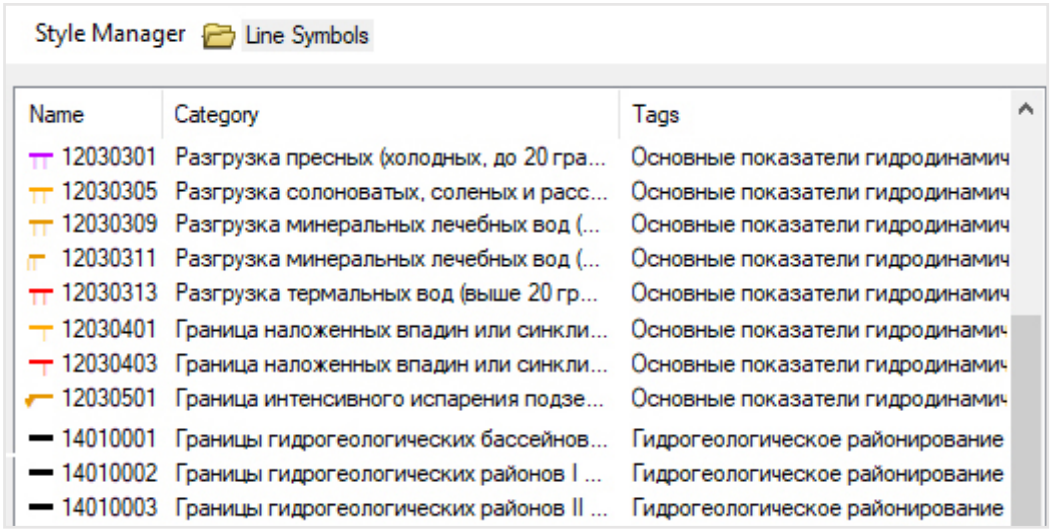
The file of styles "Hydrogeology.style" was created in ArcGIS, version 10.4.1, and contains 863 polygonal, linear and point conventional signs, as well as the styles for designing letterings on maps, headings, subheadings and legend elements [9]. The elements of the file of styles are presented in figure 1.

The library of the "Hydrogeology" style contains both conventional symbols prescribed by the 2006 instruction and "obsolete" designations of objects used in hydrogeological maps of the Soviet period.

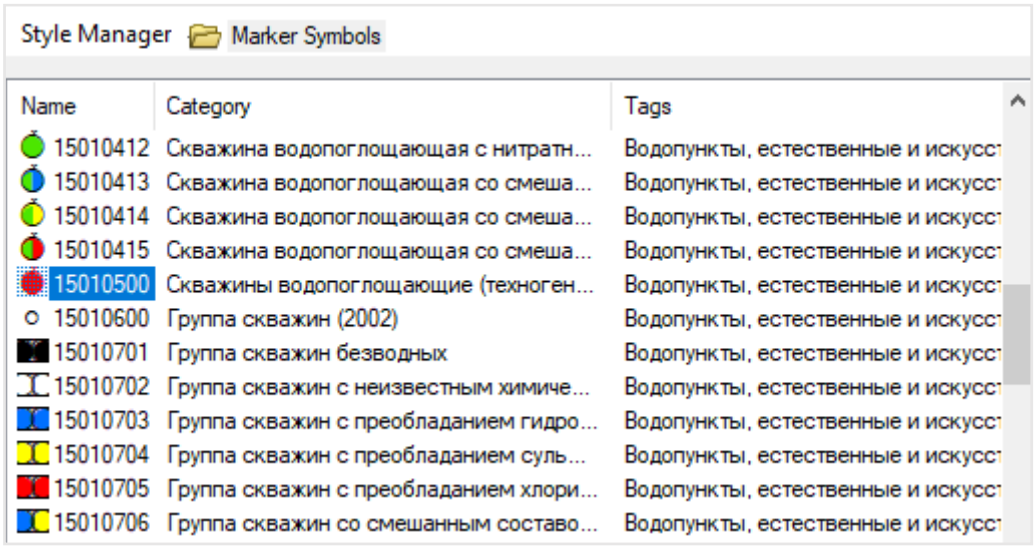
Table 1 give examples of some differences between up-to-date and "outdated" using conventional symbols and designations.

When creating point conventional signs and some types of hatching of the "Hydrogeology" style file, standard font markers of ESRI type were used. Other point conventional signs, some types of pattern and processes/objects displayed on the maps as dotted linear signs are created in ArcGIS Style Manager by combining the elements of standard font markers: ESRI AMFM Electric, ESRI Cartography, ESRI Caves 1, ESRI Default Marker, ESRI Dimensioning, ESRI Geology, ESRI Geology USGS 95-525, ESRI IGL Font22, ESRI IGL Font23, ESRI NIMA VMAP1&2 PT, as shown in figure 2.

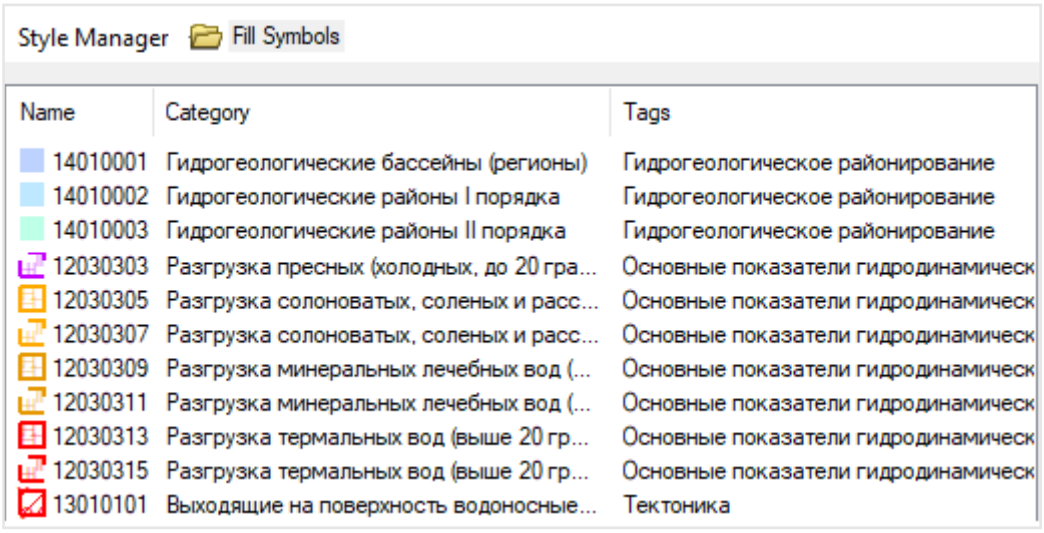
All cartographic objects of the Hydrogeology style file in ArcGIS have unique codes assigned, as shown in figure 3.



a)



b)



c)

Figure 1 – Style “Hydrogeology”:
a) linear objects; b) dotty objects; c) polygonal objects

Table 1 – Present-date and outdated notation conventions on maps

Objects or phenomena drawn on maps	Notation conventions on Soviet maps	Notation conventions in accordance with the Instruction 2006
Tectonic faults	(aquiferous fault) (non-aquiferous fault) (fault hydrogeological value of which was not figured out)	(cropping out aquiferous water-absorbing) (cropping out aquiferous water-discharging) (cropping out aquiferous water-conducting) (cropping out water-resistant) (cropping out hydrogeological unexplored)

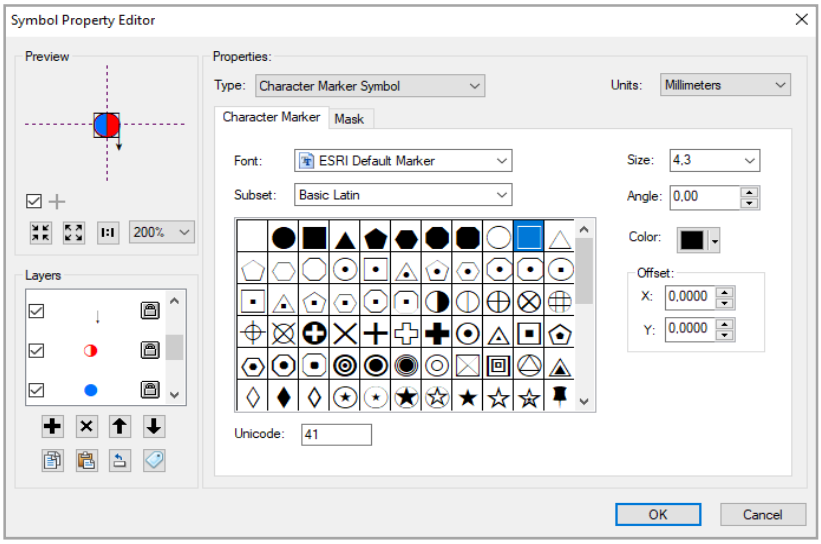


Figure 2 – Symbols creation editor

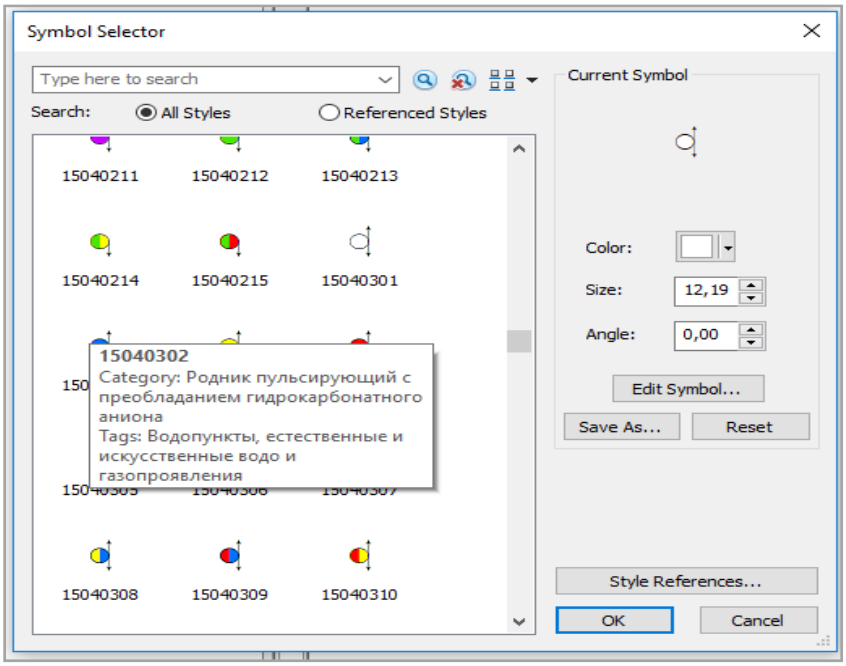


Figure 3 – Conventional symbols of “Pulsating springs” group

The unique codes of conventional signs applied in the style file correspond to the developed classifier and the geodatabase used in the sub-types and domains. The classifier is represented by an eight-digit numeric code in which each pair of characters consistently reflects information about thematic affiliation of its element, category of object, its subcategory, and the last two characters determine the unique nature of the element within the subcategory. As a result, when working with a hydrogeological map, if there is a need to show a certain class of data using conventional signs, the subtypes or domains of the attribute fields of the geodatabase with the file of styles “Hydrogeology.style” are automatically compared using the unique codes of its elements.

Conclusion. Structurization of the “Hydrogeology” style of cartographic objects in ARCGIS, use of its graphical interface and conventional signs of hydrogeological information together with a classifier and a set of attribute data, contributes to the uniformity of the digital information presented in the ArcGIS environment, which will allow specialists from a wide range of organizations using in their activities cartographic information related to hydrogeology, utilization of the technology for effective spatial analysis and data storage, and also ensure continuity archived and current cartographic information.

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ArcGIS-ДЕ ГИДРОГЕОЛОГИЯЛЫҚ ЗЕРТТЕУЛЕР НӘТИЖЕЛЕРІН ЦИФРЛАНДЫРУ

Аннотация. Кеңістіктік деректердің тұтастығын цифрландыру, біріздендіру, дамыту және қолдау мақсатында мемлекеттік геодезиялық қамтамасыз ету жүйесін жаңғырту, бірыңғай координаттар жүйесінде және деректердің бірыңғай құрылымдары бойынша карталар жасау қажет. №AP05131239 жобасы аясында геоақпараттық жүйелер көмегімен гидрогеологиялық карталарды құрылымдау бойынша ғылыми-әдістемелік негіз әзірленуде, гидрогеологиялық тақырыптағы шартты белгілер жинағы құрылды. Қазақстан Республикасында цифрлық гидрогеологиялық карталарды ресімдеудің бірыңғай әдістемесінің жоқтығына байланысты, гидрогеологиялық нысандарды біріздендіру проблемасын шешудің әдістемелік тәсілдерін әзірлеу маңызды болып табылады. Карта парақтарының сериясын құру және оларды бірыңғай шартты белгілері бар ArcGIS бағдарламалық өнімінде жұмыс істегенде пайдалану, сонымен қатар Орта Азияның басқа да елдерінде де өзекті мәселе. Бұл мақалада ArcGIS ортасында картографиялық деректердің "Гидрогеология" стилін құрылымдау кезеңі баяндалады.

Түйін сөздер: ГАЖ, цифрландыру, гидрогеология, картография, геодеректер базасы, карта.

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ЦИФРОВИЗАЦИЯ РЕЗУЛЬТАТОВ ГИДРОГЕОЛОГИЧЕСКИХ ИССЛЕДОВАНИЙ В ArcGIS

Аннотация. С целью цифровизации, унификации, развития и поддержания целостности пространственных данных необходима модернизация системы государственного геодезического обеспечения, создание карт в единой системе координат и по единым структурам данных. В рамках проекта №AP05131239 разрабатывается научно-методическая основа по структурированию гидрогеологических карт с помощью геоинформационных систем, создана библиотека условных знаков гидрогеологической тематики. Разработка

методических подходов к решению проблемы унификации гидрогеологических объектов важна в виду отсутствия единой методики оформления цифровых гидрогеологических карт в Республики Казахстан. Создание серии листов карт и использование их при работе в программном продукте ArcGIS с едиными условными обозначениями также актуально и в других странах Средней Азии]. В данной статье освещается этап структурирования стиля «Гидрогеология» картографических данных в среде ArcGIS.

Ключевые слова: ГИС, цифровизация, гидрогеология, картография, база геоданных, карта

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REFERENCES

[1] The state program "Digital Kazakhstan" approved by the Government of the Republic of Kazakhstan № 827 (2017) [Gosudarstvennaya programma «Cifrovoj Kazahstan» utverzhdennaya postanovleniem Pravitel'stva] (in Rus.).

[2] Absametov M.K., Shagarova L.V., Matushkina O.A. (2018). Library of legends of hydrogeological maps in ArcGIS // News of the National Academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 5, N 431. P. 9-11. ISSN 2518-170X (Online). ISSN 2224-5278 (Print). doi: 10.32014/2018.2518-170X.2 (in Eng.).

[3] Saidova S.A. (2018). Methodological requirements for the groundwater monitoring // Materials of the International conference «Natural global changes and technogenic conditions influence on hydrogeological, engineering geologicaland geoecological processes: analysis of results and forecasting of development». 2018. P. 89-93. ISBN 978-9943-4519-9-5 (in Rus.).

[4] http://geology.mid.gov.kz/ru

[5] Uzhkenov B.S., Kasymbekov D.A., Podolny O.V., Espaev B.A. (2006). Instruction on compilation and preparation for publication of the state hydrogeological map of Kazakhstan, scale 1:200 000. Kokshetau, 88 p. [Instrukciya po sostavleniyu i podgotovke k izdaniyu gosudarstvennoj gidrogeologicheskoj karty Kazahstana masshtaba 1:200 000.] (in Rus.).

[6] GOST 21.302-2013. Group Ж01. Interstate standard. System of design documents for construction. Conditional graphical applications in the documentation for engineering and geological surveys. [Sistema proektnoj dokumentacii dlya stroitel'stva. Uslovnye graficheskie prilozheniya v dokumentacii po inzhenerno-geologicheskim izyskaniyam.] ISS 01.100.30 (in Rus.).

[7] Murtazin Y.Z., Miroshnichenko O.L., Trushel L.Y. (2018). Methods of making of geoinformational and analytical system of groundwater resources in Kazakhstan // News of the National Academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical sciences. 2018. Vol. 5, N 431. P. 21-31. ISSN 2518-170X (Online). ISSN 2224-5278 (Print). https://doi.org/10.32014/2018.2518-170X.6 (in Eng.).

[8] Shagarova L., Muratova M., Cheredov V. On the structuring of hydrogeological maps using geoinformation systems // 18th International Multidisciplinary Scientific GeoConference SGEM 2018. 2018. Vol. 18. P. 511-518. ISBN 978-619-7408-41-6. ISSN 1314-2704. doi: 10.5593/sgem2018/2.3/S11.065 (in Eng.).

[9] Liu, Ling, Özsu, M. Tamer (2009). Encyclopedia of Database Systems Editors. Springer, Boston (in Eng.).

[10] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[11] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[12] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[13] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[14] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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STRUCTURE OF GEOINFORMATIONAL AND ANALYTICAL SYSTEM "GROUNDEWATER RESOURCES AND RESERVES OF THE REPUBLIC OF KAZAKHSTAN"

Abstract. In the context of strong man-caused impact on groundwater, the challenges of water resources management become particularly relevant, and they require significant amount of information from different areas of knowledge. Information and analytic systems can be an efficient tool for accumulating, processing and analyzing information.

The informational system "Groundwater resources and reserves of the Republic of Kazakhstan" consists of the document database, the graphic and semantic database, the database of mathematical models, the structure of those is, to a large extent, determined by the used software programs. All information of the system is divided into general and special information according to its intended purpose. The general information contains the information that underlies all hydrogeological investigations. The special information is intended to solve certain tasks of the assessment of groundwater resources and reserves.

The document database is used for accumulating all available materials, including the materials of the related areas of knowledge. The tables with structured texts constitute the semantic database. The graphic database represents a geographic information system, and contains the data, required for investigating groundwater resources and reserves. The database of mathematical models contains hydrodynamic and geomigration models. The geoinformational and analytical system is open, and can be extended by the inclusion of new information, and its structure can be updated in case of the change of the type of hydrogeological investigation.

The structure is perfectly developed to solve the task of the assessment of groundwater resources and reserves, and can be recommended for creation of the geoinformational and analytical system of groundwater resources and reserves of the Republic of Kazakhstan.

Key words: groundwater, informational systems, groundwater resources.

The intensive development of computer equipment and its availability to a wide range of scientists and specialists boosted the development of the informational systems in different fields of activities. Now informational systems are not just a final isolated product, accumulating the results of some development projects. They represent a tool for conducting scientific research, and it explains their link to the subject area.

Earth sciences, including hydrogeology, have a large amount of unsystematized, miscellaneous materials, and also data from the related areas of knowledge. The creation of information and analytic systems for accumulating, processing and analyzing the hydrogeological data has a particular significance for solving the tasks of groundwater management.

The efficiency of usage of informational systems in hydrogeology is proven by the world experience. Our article contains the review of the investigations in this area [1]. One must emphasize that the informational systems with groundwater data operate in many countries, including Russia [2], Kazakhstan [3], the USA [4, 5], Canada [6], Australia [7], Europe [8-11], China [12], Japan [13], India [14], Mongolia [15], the RSA [16], etc.

The informational system is a system that includes an ordered and organized set of data and means to manage it, designed for acquisition of new quality information about the state of an object, a process or an event [17]. The purpose of creation of the geographic geoinformational and analytical system of groundwater resources and reserves of the Republic of Kazakhstan is accumulation of the data about groundwater resources and the natural environments related to them, and its usage as an informational basis for solving the practical hydrogeological tasks. The principles that are presented in [18] form the basis of the system development methodology. It involves collecting and accumulating the data, solving the practical hydrogeological tasks, elaborating the recommendations, and providing the reference and information service [1].

The geoinformational and analytical system "Groundwater resources and reserves of the Republic of Kazakhstan" consists of the document database, the graphic database, the semantic database, and the database of mathematical models. The structure of the databases is, to a large extent, determined by the used software programs. All information of the system can be conventionally divided into general and special information according to its intended purpose. The general information contains the information that underlies all hydrogeological investigations. The close connection of groundwater with different natural environments requires the informational system to contain data from the related knowledge areas, such as geology, hydrology, meteorology, topography, etc.

The special information is intended for solving the certain tasks, in this case, the task of the assessment of groundwater resources and reserves. The special information is formed by the expert on the basis of the general information by the inclusion of additional data, and it reflects the expert's subjective point of view on the certain problem.

The hydrogeological investigations involve using and processing of a large amount of miscellaneous data from different sources. The usage of different methods of interpretation of primary data results in the subjectivity of information, therefore, all investigation results, obtained by different experts have to be stored. The document database (figure 1) is created to accumulate all available materials, including the materials of the related areas of knowledge. The main components of the document database are unpublished and published materials, and reports on the basis of the data, contained in the information and analytic system.

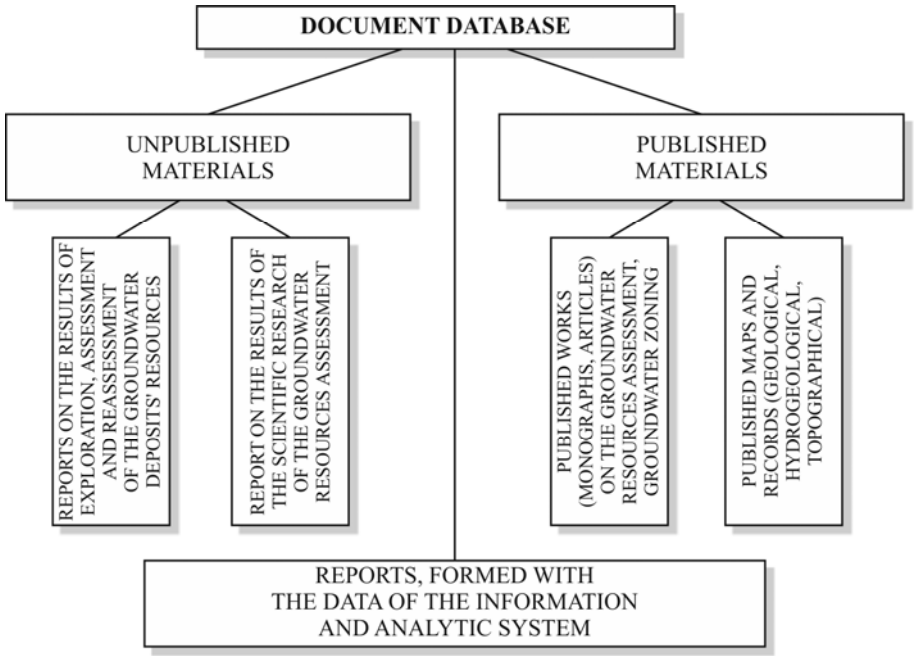


Figure 1 – Structure of the document database

The semantic database consists of a set of tables, and it constitutes the system of collection, storage and analysis of numeric and text data (figure 2). All its information can be conventionally divided into general and special information. The general information includes primary materials, values of geofiltration parameters and descriptions of the facilities used for economic activities.

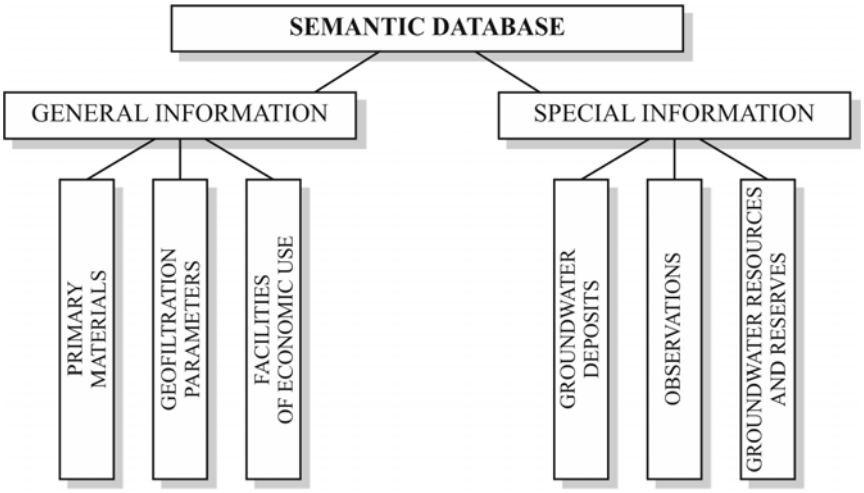


Figure 2 – Structure of the semantic database

Primary materials include descriptions of exploration and observation wells (geological and hydrogeological), results of overdrafts, and geophysical data. Geofiltration parameters are the result of processing the primary materials, and they include the coefficients of transmissibility, filtration, conductivity, piezo conductivity, elastic and gravity water yield, and migration parameters [17]. In the informational system the facilities used for economic activities are defined as man-made objects that have impact or may have impact on groundwater. Water intake structures certainly have the biggest impact on groundwater. Therefore, all data related to the groundwater deposits is allocated in the separate block of the section Special information of the informational system.

The data of the Special information section of the semantic database is used for solving the tasks of the assessment of groundwater resources. It contains the block "Groundwater deposits", the block "Observations", the block "Groundwater resources and reserves".

The block "Groundwater deposits" includes the descriptions of deposits and water intakes, as well as real and expected water intake. The block "Observations" contains the results of permanent observation of groundwater resources and the natural environments related to them, and the results of one-time observations. Groundwater, surface water and the air are monitored to assess the state of groundwater and to

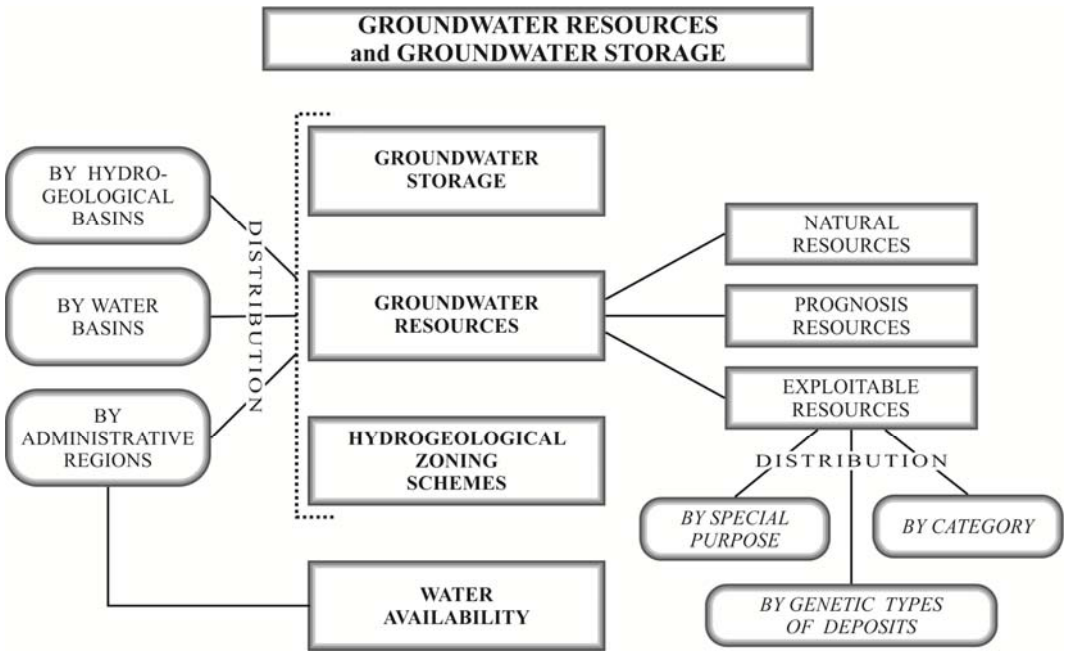


Figure 3 – Structure of the block "Groundwater resources and groundwater storage"

make forecast of its changing under anthropogenic impact. The information about groundwater resources, hydrogeological zoning plans, and groundwater resources endowment constitutes the block "Groundwater resources and reserves". The resources are estimated within the hydrogeological basins, water basins and administrative districts (figure 3).

Hydrogeological investigations are followed by the estimation of natural, expected and operational groundwater resources. The operational resources in turn can be divided according to the intended purpose, category and genetic type of the deposit [19, 20]. The estimation results are presented in the tables of the semantic database (figure 4).

DISTRIBUTION OF PROVEN EXPLOITABLE GROUNDWATER RESOURCES WITHIN THE WATER BASINS

BY SPECIAL PURPOSE						
WATER BASIN	*EXPLOITABLE RESOURCES, THOUSAND CUBIC METERS/DAY*					
	HOUSEHOLD and DRINKING WATER	*DRINKING WATER*	*IRRIGATION*	*MINERALIZATION*	*TOTAL*	*INCLUDING WITH MINERALIZATION UP TO 1 G/L*

BY GENETIC TYPES	
WATER BASIN / *GENETIC TYPE OF GROUNDWATER DEPOSIT*	*EXPLOITABLE RESOURCES, THOUSAND CUBIC METERS/DAY*
BASIN	
IN RIVER VALLEYS	
IN ARTESIAN BASINS	
IN DETRITAL CONES	
IN SANDY MASSIFS	
IN FISSURED ROCKS	

BY CATEGORY						
WATER BASIN	*SPECIAL PURPOSE OF GROUNDWATER DEPOSIT*	*EXPLOITABLE RESOURCES, THOUSAND CUBIC METERS/DAY*				
		A	*B*	*C1*	*C2*	*TOTAL*

Figure 4 – Structure of the data that demonstrates the allocation of operational reserves within the water basins

The graphic database, as a geographic information system, represents the system of collection, storage, processing, access, analysis, interpretation and graphical visualization of the spatial data. The information and analytic system "Groundwater resources and reserves of the Republic of Kazakhstan" contains the data that is necessary for studying groundwater resources, and the results of their assessment. The forms of materials presentation allow using them for solving the practical hydrogeological tasks.

The characteristics of hydrogeological information, such as a large amount of data, the necessity to consider the connection of groundwater with natural environments and man-made objects, low formalizability of the subject domain, high differentiation of the territorial data, subjectivity of the materials assessment, etc, were considered in formation of the graphic database.

The graphic database includes general and special information (figure 5). The general information shows the connection of groundwater with the environment. The general information contains hydrogeological, geological, hydrographical, meteorological information, topographical data, the facilities used for economic activities, administrative-territorial units, and the data of Earth remote probing.

The special information includes the data associated with the certain hydrogeological task of the assessment of groundwater resources. It is the results of the assessment of groundwater resources and reserves, obtained by different experts in different territories, using different methods. The names of the special information sections of the semantic database and the graphic database are the same, it is explained

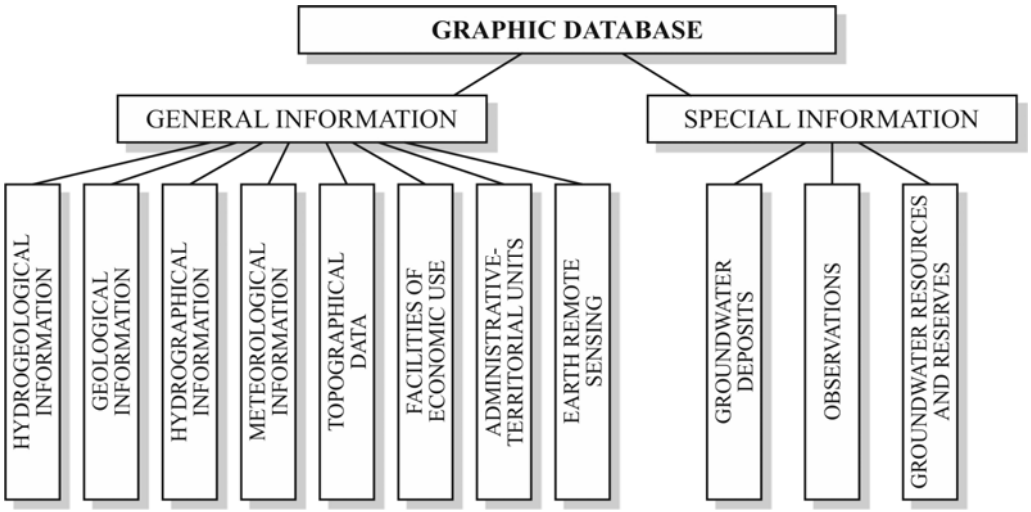


Figure 5 – Structure of the graphic database

by the specific character of the task of the assessment of groundwater resources, and the possibility to use the tables of the semantic database as attributes of graphic objects.

The unique attribute information is connected with each graphic object. It is used for data sampling, designing the thematic maps, creating the links of the spatial objects with the tables of semantic database, constructing the array of initial data for the mathematical model, etc.

The groundwater deposits are presented as point objects with the code and name of the deposit, etc. The observations in the graphic database are presented as layers of point objects of hydrogeological observation wells, hydrometeorological and hydrogeological stations, meteorological stations. The block "Groundwater resources" has the same structure as the one in the semantic database.

The results of the assessment of groundwater resources and reserves reflect the original view of the researcher; therefore, there is a variety of graphic representations of these parameters. The estimations are based on the data of lithologic age composition of hydrophilic formations, mineralization of groundwater, limits of aquiferous formations, stratification depth of groundwater, groundwater accumulation and discharge areas, tectonic faults, etc. Therefore, the maps of groundwater resources and reserves are highly important.

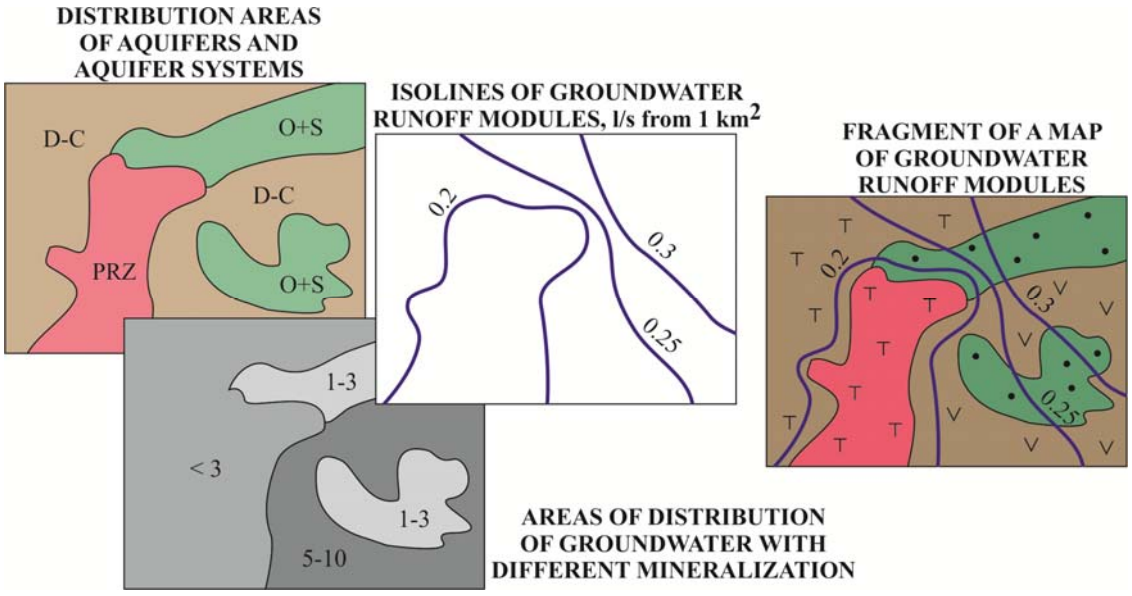


Figure 6 – Design of the map of groundwater natural resources

The maps, containing the data about groundwater resources and reserves are designed with isolines or zones. A code is connected with each graphic object. As well as this, the reserves volume or the resources flow dimension can constitute attribute information. One should note that module maps are the most demonstrative (figure 6). Module maps of groundwater resources demonstrate the flow discharge from the area unit. Resources and reserves volumes are presented in diagrams on the maps.

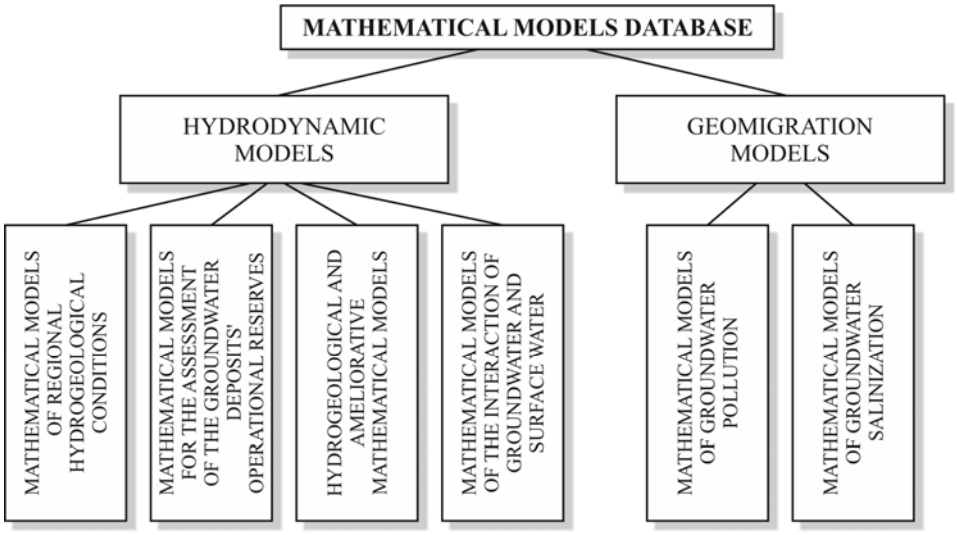
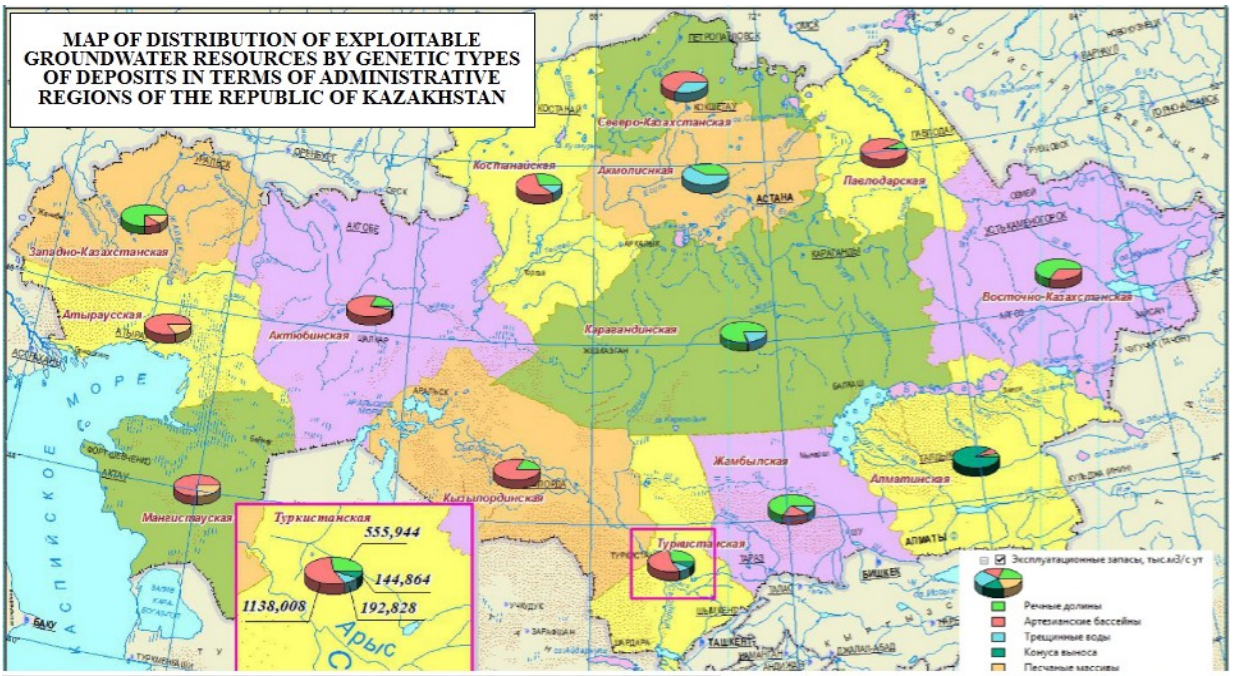


Figure 7– Structure of the mathematical models database



Administrative regions	*Usable groundwater reserves for total categories, thousand cub. m/day*					
	Genetic type of groundwater deposit					*Total*
	In river valleys	*In artesian basins*	*In the massifs of fractured rocks*	*In alluvial cones*	*In sandy*	
Akmola	166,896	0,385	249,965			
Aktobe	349,74	1451,367	79,935			
Almaty	666,797					
Atyrau	0,514					
East Kazakhstan	2211,156					
Zhambyl	1558,214					

DISTRIBUTION OF PROGNOSIS GROUNDWATER RESOURCES AND EXPLOITABLE GROUNDWATER RESOURCES BY ADMINISTRATIVE REGIONS

Administrative regions	*Undiscovered potential groundwater resources, thousand cub. m/day*			
	Total	*Mineralization, g/dm³*		
		Up to 1	*1-3*	*3-10*
				127
				3837,1
				2307,7
				3415

Administrative regions	*Usable groundwater reserves for designated purpose, thousand cub. m/day*				
	Utility and drinking water supply	*Technical and industrial water supply*	*Land irrigation*	*Mineral waters*	*Total*
Akmola	347,646	69,28		0,35	443,3

Figure 8 – Allocation of groundwater expected resources and reserves resources within the administrative regions of the Republic of Kazakhstan in the graphic and semantic databases

The informational system allows designing the maps of groundwater reserves and resources (natural, expected, operational), and hydrogeological zoning plans within administrative districts, hydrogeological and water basins. The maps of groundwater resources endowment are designed within administrative districts.

The database of mathematical models of geofiltration can be divided into two blocks, the block of hydrodynamic models and the block of geomigration models (figure 7). Hydrodynamic models include mathematical models of regional hydrogeological conditions, mathematical models for the assessment of operational resources of the groundwater deposits, hydrogeological and ameliorative mathematical models, and mathematical models of the interaction of groundwater and surface water. Geomigration models include mathematical models of the groundwater pollution and salinization.

The document database should be created in Microsoft Access, the semantic database in Microsoft Excel, the graphic database in geographic information systems ArcGIS and MapInfo, the database of mathematical models in groundwater mathematical modeling system (GMS).

The maps of expected groundwater resources and operational groundwater reserves (the block Groundwater resources and reserves of the graphic database), and associated tables (the block Groundwater resources and reserves of the semantic database) were included as an example in the geographic information and analytic system Groundwater resources and reserves of the Republic of Kazakhstan [19-21] (figure 8).

Therefore, the structure of the geographic information and analytic system “Groundwater resources and reserves of the Republic of Kazakhstan” is perfectly developed for solving the practical hydrogeological tasks that require a large amount of data. One should note that the system is open, and its structure can be updated in case of the change of the type of hydrogeological investigations.

The investigations are carried out within the framework of the project BR05236664 “Scientific-methodological, geographic information and analytical support of the rational usage and protection of groundwater of the Republic of Kazakhstan in the context of climate and anthropogenic changes”, and using the special purpose funding of the scientific-technical programs of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan.

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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫНЫҢ ЖЕР АСТЫ СУЛАРЫНЫҢ РЕСУРСТАРЫ МЕН ҚОРЛАРЫ» ГЕОАҚПАРАТТЫҚ-АНАЛИТИКАЛЫҚ ЖҮЙЕСІНІҢ ҚҰРЫЛЫМЫ

Аннотация. Жер асты суларына жоғары техногендік әсер ету шарттарында түрлі білім салаларынан алынатын мәліметтердің едәуір көлемін тарту арқылы өз есептерін шешуді талап ететін су ресурстарын басқару міндеті ерекше өзектілікке ие болуда. Деректерді жинақтау, өңдеу және талдау үшін тиімді аспап ретінде ақпараттық-аналитикалық жүйелер қолданылуы мүмкін.

«Қазақстан Республикасының жер асты суларының ресурстары мен қорлары» ақпараттық жүйесі құжаттар базасынан, графикалық және семантикалық деректер базасынан және математикалық үлгілер базасынан тұрады, олардың құрылымы, көбінесе, пайдаланылатын бағдарламалық өнімдермен анықталады. Жүйедегі бар ақпарат арналуы бойынша жалпы және арнайы болып бөлінеді. Жалпы тобына барлық гидрогеологиялық зерттеулердің негізі болып табылатын мәліметтер кіреді. Арнайы топ жер асты суларының ресурстары мен қорларын бағалау бойынша нақты есепті шешу үшін арналған.

Құжаттар базасы барлық қолда бар материалдарды, оның ішінде іргелес білім салаларына тиесілі материалдарды жинақтау үшін жұмыс жасайды. Құрамында құрылымдалған мәтіндік деректері бар кестелер семантикалық деректер базасын құрайды. Графикалық деректер базасы геоақпараттық жүйе түрінде жасалған және оның құрамына жер асты суларының ресурстары мен қорларын зерттеу үшін қажетті мәліметтер кіреді. Математикалық үлгілер базасының құрамына гидродинамикалық және геомиграциялық үлгілер кіреді. Геоақпараттық-аналитикалық жүйе ашық болып табылады және жаңа деректерді енгізу арқылы кеңейтілуі мүмкін, ал оның құрылымы гидрогеологиялық зерттеулердің түрі өзгергенде жаңартылуы мүмкін.

Жасалған осы құрылым жер асты суларының ресурстары мен қорларын бағалау есебін шешу үшін оңтайлы болып табылады және Қазақстанның жер асты суларының ресурстары мен қорларының геоақпараттық-аналитикалық жүйесін құру үшін ұсынылуы мүмкін.

Түйін сөздер: жерасты суы, ақпараттық жүйе, жерасты суы ресурстары.

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СТРУКТУРА ГЕОИНФОРМАЦИОННО-АНАЛИТИЧЕСКОЙ СИСТЕМЫ «РЕСУРСЫ И ЗАПАСЫ ПОДЗЕМНЫХ ВОД РЕСПУБЛИКИ КАЗАХСТАН»

Аннотация. В условиях высокого техногенного воздействия на подземные воды особую актуальность приобретают задачи управления водными ресурсами, требующие для своего решения привлечения значительного количества сведений из разный областей знаний. В качестве эффективного инструмента накопления, обработки и анализа данных могут выступать информационно-аналитические системы.

Информационная система «Ресурсы и запасы подземных вод Республики Казахстан» состоит из базы документов, баз графических и семантических данных и базы математических моделей, структура которых в значительной степени определяется используемыми программными продуктами. Вся информация, содержащаяся в системе, по назначению разделяется на общую и специальную. Общая содержит сведения, которые лежат в основе всех гидрогеологических исследований. Специальная предназначена для решения конкретной задачи оценки ресурсов и запасов подземных вод.

База документов служит для накопления всех имеющихся материалов, в том числе относящихся к смежным областям знаний. Таблицы, содержащие структурированные текстовые данные, составляют базу семантических данных. База графических данных реализована в виде геоинформационной системы и включает сведения, необходимые для изучения ресурсов и запасов подземных вод. Наполнением базы математических моделей являются гидродинамические и геомиграционные модели. Геоинформационно-аналитическая система является открытой и может быть расширена путем включения новых данных, а ее структура модернизирована при изменении типа гидрогеологических исследований.

Разработанная структура является оптимальной для решения задач оценки ресурсов и запасов подземных вод и может быть рекомендована для создания геонформационно-аналитической системы ресурсов и запасов подземных вод Казахстана.

Ключевые слова: подземные воды, информационные системы, ресурсы подземных вод.

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REFERENCES

[1] Murtazin E., Miroshnichenko O., Trushel L. (2018). Methods of making of geoinformational and analytical system of groundwater resources in Kazakhstan // News of Academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 5, N 431. P. 21-31. ISSN 2224-5278. https://doi.org/10.32014/2018.2518-170X.6

[2] Federal Agency for Geodesy and Cartography (ROSKARTOGRAPHY) (2019). National atlas of Russia. Groundwater resources [Federalnoe agentstvo geodezii i kartografii (ROSKARTOGRAFIYA). Natcionalnyi atlas Rossii. Resursy podzemnykh vod]. http://xn--80aaaa1bhnclcci1cl5c4ep.xn--p1ai/cd2/214/214.html (in Rus.).

[3] Institute of Geoecology of Russian Academy of Sciences (2019). Knowledge Base: Maps. Kazakhstan (in Rus.). http://hge.spbu.ru/mapgis/subekt/kazax/kazax.html

[4] USGS (2019). USGS Groundwater Data for the Nation. National Water Information System: Web Interface. https://waterdata.usgs.gov/nwis/gw

[5] National Groundwater Association NGWA (2018). State Resources (USA). https://www.ngwa.org/connect-with-your-state/State-Resources

[6] GIN (2019). Groundwater Information Network of Canada. http://gin.gw-info.net/service/api_ngwds:gin2/en/gin.html

[7] Australian Government, Bureau of Meteorology (2019). Groundwater Dependent Ecosystems Atlas. http://www.bom.gov.au/water/groundwater/gde/map.shtml

[8] European Comission (2006). Groundwater Resources maps of Europe. https://esdac.jrc.ec.europa.eu/content/groundwater-resources-maps-europe-0

[9] British Geological Survey (2015). Groundwater resources in the UK. http://www.bgs.ac.uk/research/groundwater/waterResources/GroundwaterInUK/home.html

[10] Eaufrance (2019). Portail national d'acces aux donnees sur les eaux souterraines (France). http://www.ades.eaufrance.fr/#

[11] Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) (2019). Geoscientific applications (Germany). https://www.bgr.bund.de/EN/Themen/Geodatenmanagement/Fachanwendungen/fachanwendungen_node_en.html

[12] China Geological Survey (2013). Geoinformation and Geo-archive Service. http://en.cgs.gov.cn/Activities/201603/t20160309_265988.html

[13] Geological Survey of Japan (2018). Geological Survey of Japan, AIST. https://www.gsj.jp/en/index.html

[14] India Waterportal (2009). Groundwater Information System - Data on groundwater quality and level for all states of India from 2005-09 from the Central Groundwater Board. http://www.indiawaterportal.org/articles/groundwater-information-system-data-groundwater-quality-and-level-all-states-india-2005-09

[15] The implementing agency of Mongolian Government. Mineral resources and petroleum authority (2017). Mongolia's Geological Information Catalogue System (MonGeoCat). http://mrpam.gov.mn/mrpam/webgis/indexen.html

[16] Department of Water and Sanitation of Republic of South Africa (2018). National Groundwater Information System. http://www.dwaf.gov.za/Groundwater/NGIS.aspx

[17] Yazvin A.L. (2015). Resource potential of fresh groundwaters of Russia (solution of modern problems of geological study): Dissertation for the degree of Doctor of Geological and Mineralogical Sciences, Moscow, Russia (in Rus.).

[18] Veselov V., Panichkin V. (2004). Geoinformational-mathematical simulation of hydrogeological conditions of Eastern Priaralye. Complex, Kazakhstan, Almaty. ISBN 9965-471-92-4.

[19] Veselov V.V. (2002). Hydrogeological zoning and regional assessment of groundwater resources in Kazakhstan. Kazakhstan, Almaty: Gylym. ISBN 5-628-01116-9 (in Rus.).

[20] Smolyar V.A., Burov B.V., Mustafayev S.T. (2012). Groundwater resources of the Republic of Kazakhstan // In Book: Water Resources of Kazakhstan: assessment, forecast, management. Vol. VIII. Kazakhstan, Almaty: Gylym. ISBN 978-601-7150-27-3 (in Rus.).

[21] Smolyar V.A., Burov B.V., Veselov V.V. (2002). Water resources of Kazakhstan (surface waters and groundwaters, contemporary state). Kazakhstan, Almaty: Gylym. ISBN 9965-07-125-X (in Rus.).

[22] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[23] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[24] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[25] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[26] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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IDENTIFICATION OF PROBIOTIC STRAINS BY MODERN ANALYTICAL TECHNIQUES

Abstract. A total of 14 dominant lactic acid bacteria (LAB) isolates were recovered from traditional milk products, such as camel milk, shubat, koumiss and kurt produced in the Republic of Kazakhstan in an effort to screen novel potential starter strains. In order to identify the isolates at the species level API 50 CH carbohydrate fermentation tests, MALDI TOF mass-spectrometry and 16S ribosomal RNA (rRNA) sequence analysis were performed. Four pure *Bifidobacterium* strains were isolated from a camel milk and they were identified as *Bifidobacterium crudilactis* using the 16S rRNA gene sequencing. On the other site, our results demonstrated firstly the presence of the genus *Bifidobacterium* in camel milk.

Keywords: probiotic, camel milk, shubat, koumiss, kurt, fructose-6-phosphate phosphoketolase (F6PPK), 16S rRNA sequencing.

Introduction. Lactic acid bacteria (LAB) have a long history of safe use in food fermentations and play a significant role in the manufacture of fermented milk products [1, 10]. Dairy industry is constantly exploring new possibilities to increase the diversity of dairy products in order to meet the technological needs and consumer demands. Therefore, there is a growing interest in searching for potential novel starter microorganisms from various unconventional sources, such as raw milk products [16,20] and many traditional dairy foods such as fermented yak milk and goat milk, koumiss, butter, cheese, kefir, whey and qula [2, 4, 7, 9, 11, 14, 15, 19, 21, 22]. In this paper, we describe the lactic acid bacteria isolated from three traditional Central Asian dairy products, koumiss, shubat and kurt, each manufactured by a simple backslopping procedure.

Koumiss is a fermented dairy product traditionally made from mare's milk. The drink remains important to the peoples of the Central Asian steppes, of Huno-Bulgar, Turkic and Mongol origin: Kazakhs, Bashkirs, Kalmyks, Kyrgyz, Mongols and Yakuts.

The artisanal manufacture of koumiss is based on the inoculation of raw mare's milk with previously produced koumiss. Today koumiss is made from pasteurized mare's milk by adding about 30% the previous batch, and allowing to ferment at 26-28 °C for 2-4 hours with occasional stirring. After fermentation, koumiss is bottled, capped, and stored for ripening at 4-6°C for 1-3 days. The major fermentation products are lactic acid, ethanol and carbon dioxide.

Shubat is a fermented camel milk beverage and a favorite part of daily diet for many people of Kazakhstan. Traditionally, shubat is considered useful against such diseases as asthma, tuberculosis, hepatitis, diabetes, and psoriasis. The process of shubat preparation is simple and - like tahat of koumiss - is based on backslopping. Fresh camel milk is poured into wooden container, previously made shubat is added, the container is covered and the milk left to ferment.

Kurt is a Kazakh national product manufactured from pasteurized cow, sheep or goat milk. The product is made from low-fat milk, which is pasteurized at 80-85 °C (176-185 °F) for 10-20 sec, then cooled to 32-34 °C (89.6-93.2 °F) and inoculated with the starter culture. The starter culture consisting of *Lactococci*, *Streptoccocus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* is added at a rate of 5%. The milk is incubated until the acidity reaches 75-76°Th (0.67-0.68 % titratable acidity).

Then the coagulum is heated to 38-42 °C (100.4- 107.6°F) and held at this temperature for 20-30 min to facilitate whey separation. After whey drainage the kurt is put in cloth bags, 7-9 kg at a time, and pressed until the moisture content reaches 76-80%, usually within 3-5 h. After pressing, the kurt is molded into pieces of irregular shapes weighing 25-60 g, with or without prior salting, and then air-dried at 35-40°C (95-104°F) until the moisture content is 17% or less. The final product contains not more than 17% moisture, 12% fat in the dry matter, and a maximum of 2,4% salt. It may be reconstituted with water into a beverage [3].

Here we report the taxonomic characterization of some dominant LAB species recovered from camel milk, shubat, koumiss and kurt in an effort to screen for novel potential starter strains adapted to grow in these types of products.

The methods of researches.

Sample collection. The camel raw milk, shubat and koumiss samples were collected from small villages located near the city of Almaty, Kazakhstan during the period in summer 2016. Artisanally produced kurt was collected from a farm in Kyzylorda region (Kazakhstan). After measuring the pH of the products, samples were collected aseptically into sterile tubes, kept in an ice-box and transported for analysis to the microbiology laboratory of Czech University of Life Sciences, Prague (table 1).

Table 1 – Lactic acid bacteria strains, sourse of isolation and origin

Sample	Sourse of isolation	Origin
5-2M	Shubat	Kazakhstan, Almaty
5-5M		
6-2M	Koumiss	Kazakhstan, Almaty
6-12M		
7-1M	Camel milk	Kazakhstan, Almaty
7-4M		
7-8M		
7-1C		
7-2C		
7-5C		
7-6C		
8-2M	Kurd	Kazakhstan, Kyzylorda
8-6M		
8-9M		

Isolation and cultivation of strains. One ml or 1 g of each product was mixed with 9 ml of 0.85% (w/v) sterile physiological saline. Serial dilutions were made for each sample plated in triplicate on universal and selective media: MRS agar (Difco™) for Lactobacilli and for Bifidobacteria Wilkins-Chalgren agar (Oxoid, UK) supplemented with the soybean peptone (5g/L, Oxoid), L-cysteine-HCl (0.5 g/L, Sigma-Aldrich), Tween 80 (1 mL/L, Sigma-Aldrich). Selective agents mupirocine (100 mg/L, Oxoid) and glacial acetic acid (1 mL/L; Sigma-Aldrich) were also included this medium (Rada and Petr, 2000; Ferraris et al., 2010). The plates were incubated anaerobically (BBL GasPak 100 Anerobic system, BD Biosciences, Sparks, MD, USA) at 37°C for 2–3 days. Representative single colonies from the highest dilutions were randomly selected from the agar plates and transferred into tubes containing MRS broth and anaerobic Wilkins-Chalgren broth. The isolates were cultivated for 24 h at 37 °C. Purity was checked using the light microscope.

Phenotypic studies. The biochemical properties of the strains were characterized using API 50 CHL strips (Biomerueux, France) according to the instructions provided by the manufacturer. For suspected bifidobacteria, the phosphoketolase assay was used as a diagnostic test. The cells were washed twice (10 000×*g*, 4°C, 15 min) with phosphate buffer [0.05 M KH_2PO_4, mixed 1:1 with cysteine·HCl, (500 mg/liter), pH adjusted to 6.5 with fresh NaOH] and resuspended in 1.0 ml of phosphate buffer. Washed bacterial cells either underwent no pretreatment, sonication for 6 min in ice, or were incubated with Cetyl Trimethylammonium Bromide (CTAB) for 5 min prior to the assay. CTAB was added in graded amounts of 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 ml (450 μg/ml stock solution) to determine the level of CTAB that would be effective for cell disruption.

After pretreatment, 0.25 ml of a solution containing sodium fluoride (NaF, 3 mg/ml) and potassium or sodium iodoacetate (5 mg/ml) in H_2O was added, followed by 0.25 ml sodium fructose-6-phosphate solution (80 mg/ml in H_2O). The mixture was vortexed and then incubated at 37°C for 30 min. After incubation, 1.5 ml of hydroxylamine·HCl (13 g/100 ml) was added, and the vortexed mixture was incubated at room temperature for 10 min. One milliliter of TCA (15%, W/V), 1.0 ml of 4N HCl and 1.0 ml of ferric chloride ($FeCl·6H_2O$, 5% W/V in 0.1 N HCl) were added, the tubes were vortexed and color formation was recorded either using a qualitative scale or spectophotometrically at 505 nm. For spectrophotometric determinations, the stopped reaction mixture was centrifuged (10 000×*g*, 4°C, 15 min) and the supernatant was measured using a Bausch and Lomb Spectronic 70 spectrophotometer. Test tubes containing reagents without cells, or cell suspensions with all the reagents except fructose-6-phosphate, were used as blanks.

Mass-spectrometric analysis was carried out using Autoflex MALDI TOF mass-spectrometer (Bruker Daltonics, Germany). Fresh overnight cultures and ethanol–formic acid extraction procedure were applied for the microorganism profiling. Each sample spot was overlaid with 2 μL of matrix solution (saturated solution of α-cyano-4-hydroxy-cinnamic acid in 50% acetonitrile with 2.5% trifluoroacetic acid) and again air-dried for 15 min (Bruker Daltonik GmbH, Germany). To identify the microorganisms, the raw spectra obtained for each isolate were imported into the BioTyper software, version 2.0 (Bruker Daltonik) and analyzed without any user intervention.

Identification based on 16S rRNA gene sequencing. Genomic DNAs from the bacterial strains were obtained using the commercial Genomic DNA Mini Kit applied biosystem *PrepMan Ultra* Sample Preparation Reagent (Applied Biosystems). Almost complete 16S rRNA gene fragment was amplified using primers 616V and 630R under PCR conditions as described previously [12]. Amplifications were performed with a thermal cycler (Biometra T professional gradient Thermocycler) and then confirmed using the 1.5% agarose electrophoresis (110V, 30 minutes) under the UV lamp. Checked samples were purified using the PCR purification kit (Qiagen) and sent to the GATC (Biotech company) for sequencing. The complete 16S rRNA gene sequences were reconstructed on the basis of 2 sequences, derived from forward and reverse primer. For these purposes, the BioEdit v7.2.5 program (available at: http://www.mbio.ncsu.edu/bioedit/page2.html) was used. Identification of all 14 strains was performed by comparison of obtained sequences with all 16S rRNA gene sequences included in EzTaxon database [8]. Assembly of genome and bioinformation analysis was carried out using BLAST program (www.blast.ncbi.nlm.nih.gov/blast.cgi). Obtained sequences were deposited in GenBank database using the BanKlt system (https://www.ncbi.nlm.nih.gov/WebSub/?tool=genbank) [13].

Results. Altogether 14 isolates representing the dominant colony types in the different milk and dairy product samples recovered from different geographical regions were selected for further study. The isolate codes, their species designations suggested by the different identification methods are listed in Table 2.

It can be seen that members of *Lactobacillus* and *Lactococcus* genera dominated the dairy food samples, while *Bifidobacterium* was a common finding in the raw camel milk (present at levels of 10^6 CFU per ml). Although bifidobacteria are often detected in raw milk [6], this finding was somewhat surprising, because no selective enrichment was applied before the plating in our study.

In order to confirm the species designation, the presumed *Bifidobacterium* isolates were tested for fructose-6-phosphate phosphoketolase activity. The fructose-6-phosphate phosphoketolase or transketolase assay is considered as a definitive biochemical test for the *Bifidobacterium* genus [17,18]. A limitation of the assay is the time-consuming process of cell disruption, either by use of the French Pressure Cell or by sonication. Accordingly, we replaced the cell disruption process with a more rapid cell membrane disrup-

tion process by pretreating cells with the detergent hexadecyltrimethylammonium bromide (cetrimonium bromide, CTAB). According to our results (unpublished data), the CTAB treatment produced results identical to those obtained with the conventional cell disruption procedure with known positive (*Bifidobacterium*) and negative (*Lactobacillus*) controls. The positive reaction (formation of reddish-violet color) seen with the isolates 7-1C, 7-2C, 7-5C and 7-6C confirmed the identification as *Bifidobacterium* as indicated by the 16S rRNA sequence data suggesting *B. crudilactis* as the species. This species has been previously identified as a novel species isolated from French raw milk and raw milk cheeses [5].

Table 2 – Phenotypic and genetic characterization of lactic acid bacteria

Isolate	Appr. CFU count per g or ml	Suggested species identity		
		API 50 CHL	MALDI- TOF	16s rRNA
5-2M	$6{,}6\times10^{7}$	*Lactobacillus helveticus*	*Lactobacillus ultunensis*	*Lactobacillus helveticus*
5-5M	$5{,}6\times10^{8}$	*Lactobacillus brevis*	not reliable identification	*Lb. pontis*
6-2M	$1{,}0\times10^{7}$	*Lactobacillus acidophilus*	*Lactobacillus kefiranofaciens*	*Lb kefiranofaciens*
6-12M	$1{,}6\times10^{7}$	*Lb. pontis*	not reliable identification	*Lb. pontis*
7-1M	$1{,}2\times10^{8}$	*Lact.lactis* subsp. *lactis*	*Lactococcus lactis*	*Lactococcus lactis* subsp. *lactis*
7-4M	$6{,}5\times10^{7}$	*Lact.lactis* subsp. *lactis*	*Lactococcus lactis*	*Lact.lactis* subsp. *hordiane*
7-8M	$2{,}9\times10^{8}$	*Lact.lactis* subsp. *lactis*	*Lactococcus lactis*	*Lact.lactis* subsp. *lactis*
7-1C	$2{,}6\times10^{7}$	*Lactobacillus brevis*	not reliable identification	*Bifidobacterium crudilactis**
7-2C	$4{,}8\times10^{6}$	*Lactobacillus brevis*	not reliable identification	*Bif.crudilactis**
7-5C	$2{,}2\times10^{8}$	*Lactobacillus brevis*	not reliable identification	*Bif.crudilactis**
7-6C	$1{,}7\times10^{8}$	*Lactobacillus brevis*	not reliable identification	*Bif.crudilactis**
8-2M	$9{,}2\times10^{7}$	*Lactobacillus paracasei*	*Lactobacillus paracasei*	*Lb. paracasei*
8-6M	$2{,}0\times10^{7}$	*Lactobacillus brevis*	*Lactobacillus brevis*	*Lb. brevis*
8-9M	$5{,}6\times10^{7}$	*Lactobacillus brevis*	*Lactobacillus paralimentarius*	*Lb. crustorum*

*Confirmed by phosphoketolase assay.

Discussion. The traditional fermented milk products from Central Asia have a reputation of being both highly nutritious and also health promoting. However, the evidence has largely been anecdotical, and serious investigations of the role of lactic acid bacteria or their metabolic products in the presumed health effects have only recently been started.

The technological suitability and actual probiotic efficacy of these strains have to be thoroughly assessed before their eventual applications, our results confirm the great potential of traditional Kazakh milk products as a source of novel dairy starters or probiotic cultures, as indicated in some recent studies on similar products from other geographical regions.

Conclusion. The present study represents the microbiological investigation of the traditional milk products, such as camel milk, shubat, koumiss and kurt produced in the Republic of Kazakhstan. Our results indicate the occurrence of the species *B. crudilactis* in camel milk originated from Kazakhstan area. A total of 14 dominant lactic acid bacteria (LAB) isolates were assessed for their technical suitability as starters and particularly their probiotic properties.

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ПРОБИОТИКАЛЫҚ ШТАМДАРДЫ ЗАМАНАУИ АНАЛИТИКАЛЫҚ ӘДІСТЕРМЕН ИДЕНТИФИКАЦИЯЛАУ

Аннотация. Қазақстан Республикасының түйе сүті, шұбат, қымыз және құрт тәрізді дәстүрлі сүтқышқылды өнімдерінен белсенді жаңа штамдарды скринингілеу мақсатында жалпы саны 14 доминанты өсінділер бөлініп алынды. Өсінділерді түрге дейін ажырату үшін көмірсулардың ферменттелу API 50 CH тесті, MALDI TOF масс-спектрометриясы және 16S рибосомалық РНҚ (рРНҚ) дәйектілігі бойынша талдау жүргізілді. Bifidobacterium тобының 4 жаңа штамдары түйе сүтінен бөлініп алынып, олар 16S рРНҚ генін секвенирлеу арқылы Bifidobacterium crudilactis екені анықталды. Екінші жағынан, біздің зерттеу нәтижелеріміз алғашқы рет түйе сүтінде Bifidobacterium тобының кездесетініндігін дәріптейді.

Түйін сөздер: пробиотик, түйе сүті, шұбат, қымыз, құрт, фруктоза-6-фосфат-фосфокетолаза (F6PPK), 16S р РНҚ секвенирлеу.

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ИДЕНТИФИКАЦИЯ ПРОБИОТИЧЕСКИХ ШТАММОВ СОВРЕМЕННЫМИ АНАЛИТИЧЕСКИМИ МЕТОДАМИ

Аннотация. В общей сложности 14 доминантных изолятов молочнокислых бактерий были выделены из традиционных молочных продуктов, таких как верблюжье молоко, шубат, кумыс и курт, произведенных в Республике Казахстан, в целях скрининга новых потенциальных штаммов заквасок. Для идентификации изолятов на уровне видов были проведены тесты ферментации углеводов API 50 CH, масс-спектрометрия MALDI TOF и анализ последовательности 16S рибосомальной РНК (рРНК). Четыре чистых штамма Bifidobacterium были выделены из верблюжьего молока, и они были идентифицированы как Bifidobacterium crudilactis с использованием секвенирования гена 16S рРНК. С другой стороны, наши результаты первый раз продемонстрирует наличие рода Bifidobacterium в верблюжьем молоке.

Ключевые слова: пробиотик, верблюжье молоко, шубат, кумыс, курт, фруктоза-6-фосфат-фосфокетолаза (F6PPK), 16S р РНК секвенирование.

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REFERENCES

[1] Airidengcaicike C.X., Du X., Wang W., Zhang J., Sun Z., Liu W., Li L., Sun T., Zhang H. 2010. Isolation and identification of cultivable lactic acid bacteria in traditional fermented milk of Tibet in China // Int. J. Dairy Technol. 63:437-444.

[2] Badis A., Guetarni D., Moussa-Boudjemaa B., Henni D., Tornadijo M., Kihal M. 2004. Identification of cultivable lactic acid bacteria isolated from Algerian raw goat's milk and evaluation of their technological properties // Food Microbiol, 21: 343-349.

[3] Joseph A., Kurmann Jeremija Lj. Rasic Manfred Kroger. 1992. Encyclopedia of Fermented Fresh Milk Products // An International Inventory of Fermented Milk, Cream, Buttermilk, Whey, and Related Products, Van Nostrand Reinhold 115, New York, 10003.

[4] Chen X., Du X., Wang W., Zhang J., Sun Z., Liu W., Li L., Sun T., Zhang H. 2010. Isolation and identification of cultivable lactic acid bacteria in traditional fermented milk of Tibet in China // Int. J. Dairy Technol.; 63:437–444. doi: 10.1111/j.1471-0307.2010.00595.x

[5] Delcenserie V., Gavini F., Beerens H., Treese O., Franssen C., Daube G. 2007. Description of a new species, Bifidobacterium crudilactis sp.nov. isolated from raw milk and raw milk cheeses // System. Appl. Microbiol. 30:381-389.

[6] Delcenserie V., Bechoux N., China B., Daube G., Gavini F. 2015. A PCR method for detection of bifidobacteria in raw milk and raw milk cheese: comparison with culture-based methods // J. Microbiol. Methods. 6155-6167.

[7] Duan Y.H., Tan Z.F., Wang Y.P. Z.W., Li Z.Y., Qin G.Y., Huo Y.P., Cai Y.M. 2008. Identification and characterization of lactic acid bacteria isolated from Tibetan qula cheese // J. Gen. Appl. Microbiol. 54:51–60.

[8] Kim O., Cho Y., Lee K., Yoon S., Kim M., Na H., Park S.C., Jeon Y.S., Leej H., Yi H., Won S., Chun J. 2012. Introducing Eztaxon-e: a prokaryotic 16S rRNA gene sequence database with phylotypes that represent uncultured species // Int. J. Syst. Evol. Microbiol. 62:716-721.

[9] Kongo J.M., Ho A.J., Malcata F.X., Wiedmann M. 2007. Characterization of dominant lactic acid bacteria isolated from Sao Jorge cheese, using biochemical and ribotyping methods // J. Appl. Microbiology. 103: 1838-1844.

[10] Liu S.N., Han Y., Zhou Z. J. 2011. Lactic acid bacteria in traditional fermented Chinese foods // Food Res. Int. 44:643-651. doi: 10.1016/j.foodres.2010.12.034

[11] Liu W., Sun Z., Zhang J., Gao W., Wang W., Wu L., Sun T., Chen W., Liu X., Zhang H. 2009. Analysis of microbial composition in acid whey for dairy fan making in Yunnan by conventional method and 16S rRNA sequencing // Curr. Microbiol. 59:199-205. doi: 10.1007/s00284-009-9423-x

[12] Loy A., Lehner A., Lee N., Adamczyk J., Meier H., Ernst J., Schleifer K., Wagner M. 2002. Oligonucleotide microarray for 16S rRNA gene-based detection of all recognized lineages of sulfate-reducing prokaryotes in the environment // Appl. Environ. Microbiol. 68 :5064-5081.

[13] Omarova A., Mekadim Ch., Bunesova V., Killer J., Vojtech R., Tulemisova Zh. 2016. Isolation and characterization of *Bifidobacterium crudilactis* from camel milk originated from the Kazakhstan area // International Masaryk Conference for PhD students and young researchers. Vol. VII, 1693-1700.

[14] Turovskaya S.N., Galstyan A.G., Radaeva I.A., Petrov A.N., Illarionova E.E., Ryabova A.E., Assembayeva E.K., Nurmukhanbetova D.E. (2018) Scientific and practical potential of dairy products for special purposes // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. Vol. 6, N 432(2018). P. 16-22. https://doi.org/10.32014/2018.2518-170X.31 ISSN 2518-170X(Online), ISSN 2224-5278(Print).

[15] Ouadghiri M., Vancanneyt M., Vandamme P., Naser S., Gevers D., Lefebvre K., Swings J., Amar M. 2009. Identification of lactic acid bacteria in Moroccan raw milk and traditionally fermented skimmed milk 'lben' // J. Appl. Microbiol. 106:486–495. doi: 10.1111/j.1365-2672.2008.04016.x

[16] Ouadghiri M., Vancanneyt M., Amar M., Swings J. (2005) Biodiversity of lactic acid bacteria in Moroccan soft white cheese (jben) // FEMS Microbiol. Lett. 2: 267-271.

[17] Scardovi V., Trovatelli L.D. 1965. The fructose-6- phosphate shunt as peculiar pattern of hexose degradation in the genus Bifidobacterium // Ann. Microbiol. 15:19-29.

[18] Scardovi V., Trovatelli L.D., Crociani F., Sgorbati B. 1969. Bifidobacteria in bovine rumen. New bifidobacterial in calf rumen 473 species of the genus Bifidobacterium: B. globosum n. sp. and B. ruminale n. sp. Arch. // Mikrobiol. 68:278-294.

[19] Watanabe K., Fujimoto J., Sasamoto M., Dugersuren J., Tumursuh T., Demberel S. 2008. Diversity of lactic acid bacteria and yeasts in Airag and Tarag, traditional fermented milk products of Mongolia World J. Microbiol. Biotechnol. 24:1313-1325. doi: 10.1007/s11274-007-9604-3

[20] Wouters J.T.M., Ayad E.H.E., Hugenholtz J., Smit G. 2002. Microbes from raw milk 439 for fermented dairy products. International Dairy Journal, 12, 91-109.

[21] Zhang H., Xu J., Wang J., Sun T., Li H., Guo M. 2008a A survey on chemical and microbiological composition of kurt, naturally fermented yak milk from Qinghai in China // Food Control. 19: 578-86.

[22] Zhang W.Y., Yun Y.Y., Sun T.S., Menghe B., Zhang H.P. 2008b. Isolation and identification of dominant microorganisms involved in naturally fermented goat milk in Haixi region of Qinghai // China Annal. Microbiol. 58:213-217.

[23] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[24] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[25] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[26] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[27] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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CHANGE OF FORMATION CONDITIONS OF GROUNDWATER OF KAZAKHSTAN UNDER THE INFLUENCE OF ANTHROPOGENIC CHANGES OF THE ENVIRONMENT

Abstract. Anthropogenic environmental changes in Kazakhstan lead to changes in the formation of groundwater. The anthropogenic impact on the environment is expressed in the change of the relief and hydrographic network, the redistribution of water resources and the change in their qualitative and quantitative characteristics. An important consequence of anthropogenic influence is a change in the temperature regime of the territory and the nature of precipitation. The results of the analysis of the nature of changes in the formation of groundwater are given. The areas with the most strongly changed formation conditions, which include zones of ecological disaster in the Aral Sea region and the Semipalatinsk nuclear test site, as well as built-up areas of large industrial centers and urban agglomerations of cities, are identified. A comprehensive analysis of climatic, glaciological and hydrogeological materials on the territory of Kazakhstan was used as a research methodology to determine the influence of climatic and anthropogenic environmental changes on the formation conditions of groundwater. Comparison of the research results from different years with the materials of recent years identified that fundamental changes in the quantitative indicators of groundwater supply should not be expected and groundwater resources, unlike surface water resources, will not significantly decrease. The use of research results will allow justifying the expansion of water supply for the population at the expense of groundwater.

Key words: regularities of formation, groundwater, anthropogenic changes, water supply.

Introduction. The conditions of groundwater formation in Kazakhstan are determined by a combination of natural factors, the main of which are climatic conditions, the geological structure and the influence of human activity. The processes of changing geological conditions take so long periods of time that they can be considered as unchanged compared with the time of the civilization development. Climatic changes also take considerable time periods, however the parameters of changes can be well confident detected by long-term observations. The most rapidly changing factor in the formation of groundwater is human economic activity significantly changing the physiographic conditions of the groundwater formation.

The methods of researches. As a research methodology, we used a comprehensive analysis of climatic, glaciological and hydrogeological materials on the territory of Kazakhstan in order to determine the impact of climatic and anthropogenic environmental changes on the groundwater formation conditions.

The main changes in physiographic conditions that most strongly affect the conditions for the groundwater formation:

- changes in the terrain during the development of mineral resources (Karaganda and East Kazakhstan regions), during the construction of settlements and hydraulic structures on the rivers Zhaiyk, Ertis and Esil;

- changes in the hydrographic network as a result of the construction of hydropower facilities (the Zhaiyk river), the construction of irrigation systems (the Syrdarya, Ile and Karatal rivers), the redistribution of surface water between river basins during the construction of navigable and watering canals;

- changes in the composition of vegetation, the composition and conditions of soil moisture as a result of agricultural and forest management activities;

- changes in the composition of atmospheric air as a result of fuel combustion and violation of surface air circulation in built-up areas, as well as emissions of technological waste gases;

- change of the groundwater level conditions under the influence of:

- lowering the level of large bodies of water (Aral Sea);
- groundwater exploitation for water supply and irrigation;
- irrigation and drainage measures in agriculture;
- drainage measures in the extraction of minerals;
- changes in the conditions of supply and discharge of groundwater in built-up areas;

The main changes in climatic conditions that most strongly influence and determine the conditions for the formation of groundwater:

- a change in the temperature regime of the territory is an important factor in changing the conditions for the groundwater formation. In recent years, there has been an increase in the level of the average temperature in Kazakhstan - an average of about 1.8°C within 100 years, which is more than 2 times higher than the world values. An increase in air temperature causes an increase in evaporation and reduces the amount of groundwater supply, i.e. reduces the amount of groundwater resources;

- change in air temperature, expressed in global warming and the associated increase in extreme weather events such as storms, rainfalls, fog, floods, etc. Annual floods in certain areas of our country are a direct consequence of these anomalies. During the period from 1990 to 2016, the number of heavy snowfalls increased 2.5 times, the number of heavy rains increased 2.7 times, the number of heavy fogs increased more than 2 times, dust storms occur 3.4 times more often. Almost 2 times increased floods on mountain rivers. The number of mudflows increased by 2 times. According to the Kazgidromet observation network, the air temperature has increased throughout the territory of Kazakhstan in all months of the year for several decades. The average annual temperature in Almaty 100 years ago was about 7 °C, and in 2016 - 12 °C (an increase by5 degrees);

- changing of the conditions of atmospheric air circulation;

- change in the distribution of precipitation by area and time. In the long-term section, the amount of precipitation on the territory of Kazakhstan for the year practically does not change, there is only a slight increase in the northern and mountainous regions. There is more rainfall became that falls in the form of showers;

- changing of the conditions of evaporation and transpiration.

The greatest changes in the conditions of groundwater formation under the influence of natural and anthropogenic factors are confined to industrial centers and urban agglomerations, as well as to zones of ecological disaster in the Aral Sea region and at the Semipalatinsk nuclear test site. Active, increasing from year to year, changes in air temperature, precipitation and evaporation, as well as human interaction with the natural environment, acquired in the new millennium features of a global change in the anthropogenic and climatic process.

The greatest changes in the conditions of formation of groundwater under the influence of natural and anthropogenic factors are confined to industrial centers and urban agglomerations, as well as to zones of ecological disaster in the Aral Sea region and at the Semipalatinsk nuclear test site.

Active, increasing from year to year, changes in air temperature, precipitation and evaporation, as well as human interaction with the natural environment, acquired features of a planetary change in the anthropogenic and climatic process in the millennium that has come. Global anthropogenic warming of the climate, which began in the post-industrial period, poses a certain threat to the environmental habitat of modern human, because estimates of the World Meteorological Organization show that global temperature rise on Earth may reach 2.7-3.5°C by the end of the XXI century [1]. Possible climate changes in Kazakhstan by 2030, 2050 and 2085, relative to the base period of 1961-1990, can be as

follows: + 1.4°C, + 2.7°C and + 4.6°C, respectively, [2], although the amount of precipitation will increase slightly : at 2%, 4% and 5% per year, respectively.

The values of meteorological quantities for a long observation period are not a set of homogeneous statistical data, since over the years the conditions of observations have changed, as well as the influence of the main climate-forming factors, the influence of anthropogenic factors on the conditions of the weather station. For example, it is impossible to compare the conditions of the weather station of Karaganda or Almaty 30-40 years ago and now. At the moment, it is surrounded by numerous enterprises, including those with active transport movement around the meteorological station.

To clarify the trend of the average annual temperature on the territory of Kazakhstan, the meteorological data of six stations located in different regions of Kazakhstan were processed. For example, instrumental observations carried out for 30–60 years in the mountainous regions of South and Southeast Kazakhstan showed that the average annual air temperature here increased by 0.1–0.3°C every ten years. According to the developed scenarios [3], during the period up to 2050-2075a higher temperature is expected in the mountainous regions of these territories. At elevations above 1500 m, this increase may be 1.5-5.5°C.

It has been determined that the glaciation of the mountains of Central Asia from the middle of the 20th century was mainly in a state of degradation, accelerated since the early 1970s. A study of the dynamics of glaciation in the mountains of southeastern Kazakhstan in comparison with the results of the assessment of changes in glaciation in other mountainous regions shows that, like in most glacial regions of the world, until the early 1970s, glaciers remained here in a relatively stable state. However, this situation has changed in recent decades due to global warming, as evidenced by glaciological studies in the Central Asian region [4]. The rates of degradation of Central Asian glaciers are among the highest in the world: 0.8% of the area and 1% from volume per year. If the general trend of changes in the temperature regime of the territory in the coming decades continues, the melting of glaciers will continue. At the same time, despite the reduction of glacier resources with an average intensity of about 1% per year, the norms of river flow and its intra-annual distribution remained relatively stable during the last half-century, which gives grounds for Kazakhstan glaciologists to assume the existence of a compensation mechanism that ensures this stability under conditions of glaciation degradation. The role of such a mechanism is supposedly performed by the melt waters of underground ice, buried (moraine-covered) glaciers and rock glaciers. And since the ground ice reserves in the mountains of the region are comparable with the ground glaciation resources, the researchers believe that if the amounts of precipitation and maximum snow reserves in the zone of flow formation remain in stability that is characteristic for the last decades, the compensation mechanism may last for more than one century. This gives reason to hope for the relative stability of the norms of river flow and regional water resources for at least the coming decades.

As for groundwater, there was practically no special research on the upcoming changes in their resources, due to global warming. This is due to the existing opinion that groundwater is better protected from adverse climatic factors due to deep deposition. Even in the Sahara desert, the sandy massifs of Western and Southern Kazakhstan, where the air temperature is high and very little precipitation falls, there is fresh groundwater.

However, there are areas where the moisture cycle is intense, groundwater resources are being updated very actively. These areas include mountainous areas of South and South-Eastern Kazakhstan, which are distinguished by special conditions for the groundwater formation, depending on the orographic and climatic conditions. Here, permafrost has the greatest influence on the conditions of groundwater supply; its thickness increases with height: the gradient values of the increase in the thickness of the frozen zone per 100 m height are at least 10-20 m. The maximum thickness of the frozen zone at altitudes of 3100 m reaches 60 m, 3500 m - about 130-140 m, at 4000 m - more than 200 m, and at an altitude of 5000-6000 m - several hundred meters [5,6]. As can be seen from the above data, already at altitudes of 3200-3400 m, the thickness of frozen rocks becomes significant. In these conditions, the characteristics of groundwater recovery will be completely different than in areas where there is no permafrost. According to the data given in [7], in the high part of the mountains, solid permafrost acts as an aquitard. It prevents the infiltration of precipitation and snow melt water. For this reason, small groundwater resources are formed here mainly due to the melting of ice located in rock cracks, under the influence of deep heat co-

ming from the lower layers of the earth's crust. Groundwater in this area is very deep, as evidenced by the absence of natural water manifestations in the form of springs, as well as groundwater flow into rivers [7]. Below the permafrost zone, the conditions for groundwater recovery are more favorable, as evidenced by the numerous springs emerging in depressions of the relief, and the large size of the groundwater flow into the rivers. For example, at the latitude of the Tuyuksu tourist base in Zailiysky Ala Tau (abs. 2500 m), the underground flow into the M. Almatinka river reaches 35 l/s per 1 km^2 of its catchment basin. As the level of the mountain slope decreases, the magnitude of the formed groundwater becomes smaller. At altitudes of 1900-2100 m, it is 18-20 l/s per 1 km^2.

From the data presented, there is a clear increase in the module of the natural resources of groundwater as the height of the mountain slope increases. In the light of what has been noted, let us imagine the case when by the end of this century, in the mountainous regions of South and South-East Kazakhstan, the air temperature, as compared with the present, will increase by 3.5°C (the average between the forecasted 1.5-5.5°C). Such a change in the temperature conditions of a mountainous area can lead to a change in the snow line in the mountains, movement (raising) of the permafrost distribution boundary, and it is even possible that glaciers will degrade strongly until they disappear completely [3.8].

Of all the noted changes in the natural conditions of the mountainous area in the future, the movement of the high-altitude boundary of the distribution of permafrost can have the greatest impact on groundwater. The scale of this process can be judged on the basis of gradient indicators of permafrost development. According to research data [9, 10], for every 100 m of elevation of elevations in mountainous areas (above 1500 m), the temperature falls by 0.6°C, i.e. with an increase in air temperature of 3.5°C, the permafrost boundary may rise by 583 m. Such changes in general may have a favorable effect on the conditions of recovery of groundwater resources. First of all, by reducing the area occupied by permafrost, the area of intensive feeding of groundwater will increase. For example, in Zailiysky Alatau in the basin of the Bolshaya Almatinka river, such an increase will amount to 103 km^2, Malaya Almatinka - 28.2, Talgar -144, Issyk-71 and Turgeni -193 km^2. The amount of groundwater supply in the northern slope of the Zailiysky Alatau at altitudes of 2000–3000 m varies from 25–27 in the basin of Bolshaya Almatinka to 30–35 l/s per km^2 in the basin of Malaya Almatinka.

As the absolute elevations of the catchment area increase, it is legitimate to suppose an increase in the emerging groundwater resources, especially according to the research materials of I. S. Sosedov [9], in the range of 3000-4000 m in Zailiysky Alatau, the greatest amount of precipitation falls, amounting to 1300-1400 mm per year, or 40% more than in the area of modern supply. Considering the above, groundwater supply in the freeing part of the mountains from permafrost as a result of climate warming can be much larger. This is quite possible, since as a result of climate warming, an increase in evaporation from the ocean surface and, accordingly, of precipitation falling on land is expected. Thus, global warming can improve supply conditions and form additional groundwater flow. In the Kyrgyz Alatau, such movement of the permafrost boundary can take place only in the basins of the Aspara and Merke rivers. Unlike Zailiysky Alatau, the lower boundary of permafrost here is located at around 3400 m [11, 12]. When raising its border by 583 m, permafrost rocks almost completely disappear in the basins of these rivers, or the groundwater recharge area will increase by 176.4 km^2, including 115 km^2 in the Aspara river basin and 61.4 km^2 in Merke.

Results of works. On the whole, planetary climate warming will not cause significant changes in the magnitude of groundwater supply in the conditions of the Trans-Ili and Kyrgyz Alatau. However, its quantitative assessment at the present stage of the study of the hydrogeological conditions of the high-mountain zone remains unsolved.

The research results will be in demand in the research and production sphere, which deals with water resources, environmental problems, groundwater search and the agrarian sector of the republic.

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ҚОРШАҒАН ОРТАНЫҢ АНТРОПОГЕНДІК ӨЗГЕРІСТЕРІНІҢ ӘСЕРІНЕН ҚАЗАҚСТАННЫҢ ЖЕР АСТЫ СУЛАРЫНЫҢ ҚАРЫПТАСУ ЖАҒДАЙЛАРЫНЫҢ ӨЗГЕРУІ

Аннотация. Қоршаған ортаның антропогендік өзгістері Қазақстандағы жер асты суларының қалыптасу жағдайларының өзгеруіне әкелді. Қоршаған ортаға антропогендік әсер, жер бедері мен гидрографиялық желілердің өзгеруімен, су ресурстарын қайта бөлу және олардың сапасы мен сандық көрсеткіштерінің өзгеруімен сипатталады. Аймақтың температуралық режимі мен атмосфералық жауын-шашын антропогендік әсердің маңызды салдары болып табылады. Жер асты суларының қалыптасу жағдайларының өзгеру сипаттамаларына қорытынды жасалды. Арал маңы мен Семей аудандарының экологиялық апатты белдемдеріне жататын, сонымен қатар ірі өнеркәсіптік орталықтар және қала агломерация аймақтары салынған қалыптасудың неғұрлым қатты өзгеріске ұшыраған аймақтары бөлінді. Қоршаған ортаның жер асты суларының қалыптасуына климаттық және антропогендік өзгерістердің әсерін анықтау мақсатында Қазақстан аймағының климаттық, гляциологиялық және гидрогеологиялық материалдарына толық талдау жасау зерттеудің әдістемесі ретінде қолданылды. Әр жылдардағы және қазіргі кездегі зерттелген жұмыстарды салыстырғанда, жер асты суларының қоректенуіндегі сандық көрсеткіштердің іргелі өзгерістерге ұшырамағаны, сонымен қатар жер асты суларының жер беті суларына қарағанда айтарлықтай азаймайтыны анықталды. Зерттеу нәтижелерін қолдану жер асты сулары есебінен елді-мекендерді сумен қамтамасыз етуді кеңейтуге мүмкіндік береді.

Түйін сөздер: қалыптасу жағдайлары, жер асты сулары, антропогендік өзгерістер, сумен қамтамасыз ету.

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ИЗМЕНЕНИЕ УСЛОВИЙ ФОРМИРОВАНИЯ ПОДЗЕМНЫХ ВОД КАЗАХСТАНА ПОД ВЛИЯНИЕМ АНТРОПОГЕННЫХ ИЗМЕНЕНИЙ ОКРУЖАЮЩЕЙ СРЕДЫ

Аннотация. Антропогенные изменения окружающей среды в Казахстане ведут к изменениям условий формирования подземных вод. Антропогенное воздействие на окружающую среду выражается в изменении рельефа и гидрографической сети, перераспределению водных ресурсов и изменению их качественных и количественных характеристик. Важным следствием антропогенного влияния является изменение температурного режима территории и характера выпадения атмосферных осадков. Приводятся результаты анализа характера изменения условий формирования подземных вод. Выделены районы, с наиболее сильно измененными условиями формирования, к которым отнесены зоны экологического бедствия в Приаралье и Семипалатинского ядерного полигона, а также застроенные территории крупных промышленных центров и городских агломераций городов. В качестве методологии исследований использовался комплексный анализ климатических, гляциологических и гидрогеологических материалов па территории Казахстана с целью определения влияния климатических и антропогенных изменений окружающей среды на условия формирования подземных вод. В результате сопоставления результатов исследований разных лет с материалами современного последних лет установлено, что кардинальных изменений в количественных показателях питания подземных вод не следует ожидать и ресурсы подземных вод в отличие от ресурсов поверхностных вод существенно не сократятся. Использование результатов исследований позволит обосновать расширение водоснабжения населения за счет подземных вод.

Ключевые слова: закономерности формирования, подземные воды, антропогенные изменения, водоснабжение.

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REFERENCES

[1] Global and regional climate changes, their natural and socio-economic consequences. M.: Geos, 2000. P. 420.

[2] IPCC, 2001: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment of the Intergovernmental Panel on Climate Change-Cambridge University Press. Cambridge. United Kingdomand NewYork, NY, USA, 2001. P. 881.

[3] Dolgikh S., Smirnova E., Sabitayeva A., Ilyakova R. Climatic scenarios. Mountain areas of South and South-East Kazakhstan // A summary for persons determining the socio-economic and environmental policies. Almaty, 2001. P. 12-14.

[4] Water resources of Kazakhstan: assessment, forecast, management // Snow-ice resources of Kazakhstan / Seversky I.V., Kokarev A.L., Pimankina N.V. Vol. IV. Almaty, 2012. P. 246.

[5] Gorbunov A.P. Frozen phenomena of the Tien Shan. M., 1970. P. 265.

[6] Gorbunov A.P., Seversky E.V. Geocryological altitudinal zonality of the Northern Tien Shan // Cryogenic phenomena of Kazakhstan and Central Asia. Yakutsk, 1979. P. 67-83.

[7] Dzhakelov A.K. Subglacial and subfrozengroundwaters of the northern slope of the Zailiysky Alatau // Reports of the Ministry of Sciences-AS of the Republic of Kazakhstan. 1995. N 6. P. 52-59.

[8] Golitsyn G.S. Climate change in the XX and XXI centuries // Izv. Academy of Sciences of the USSR. Ser. physics of the atmosphere and ocean. 1989. Vol. 22, N 2. P. 235-249.

[9] Sosedov I.S. Methods of territorial water balance generalizations in the mountains. Alma-Ata, 1980. P. 149.

[10] Sosedov I.S., Filatova L.N., Kiktenko O.V. and others. Water balance and water resources of the northern slope of the Dzungarian Alatau. Alma-Ata, 1984. P. 150.

[11] Sosedov I.S., Filatova L.N., Kiktenko O.V. The runoff from the mountain frame of the Muyunkum artesian basin and its role in the groundwater formation and their renewable resources (manuscript). Alma-Ata, 1976. P. 175.

[12] Osipov S.V., Livinsky Yu.N., Ermenbay A.M., Gafurov Zafar. The forming of fresh underground waters of the Akmola region // "Izvestiya" National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 5, N 431. P. 18-20. https://doi.org/10.32014/2018.2518-170X.1 ISSN 2518-170X (Online). ISSN 2224-5278 (Print).

[13] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[14] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[15] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[16] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[17] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[18] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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THE LAWS OF FORMATION OF GROUNDWATER RESOURCES ON THE TERRITORY OF KAZAKHSTAN AT THE EXPENSE OF SURFACE AND GROUNDWATER

Abstract. The study of hydrogeological structures and the establishment of the relation between surface river water and groundwater. The processes of underground recharging of rivers during the low water season contribute to the preservation of the natural balance of ecosystems, ensuring the normal state of the vegetation cover of the adjacent territories, biota survival and reproduction. The interrelation between surface and groundwater of different geomorphological regions is shown; these regions are represented by mountain, piedmont and flat relief. Regularities in the groundwater formation and the influence of relation to river systems surface runoff on them have been established. Such a relation helps to maintain the ecosystem ecological stability in arid climate conditions, by redistributing the water runoff of hydrogeological systems with the aquifers of river valleys alluvial deposits. During this period the preservation of water exchange between the groundwater aquifers of river valleys alluvial deposits and overlying water-bearing formations makes it possible to maintain a stable state of the surrounding natural environment due to water exchange. A flow diagram of the interrelation between the individual elements of the water balance of the active water exchange zone (precipitation, water infiltration in the aeration zone, firstly from the surface of the aquifers, sloping on-site and groundwater runoff etc.) is presented for illustrative purposes in this work. Separately, a methodology is given for studying and carrying out quantitative assessment of the interrelation between river and groundwater in the features of the of groundwater runoff formation.

Keywords: surface runoff and groundwater runoff, natural (annually renewable) resources.

Introduction. Regional assessment of the interrelation between surface and groundwater, the objective quantitative indicator of which is the groundwater run-off to the rivers, as well as the reverse process of groundwater recharging due to stream run-off during the spring flood, are of great scientific and applicable merit. The accurate accounting of all components of surface runoff and groundwater runoff of the territories is of great practical importance in arid climate conditions for solving the problems of water supply to the population and economic sectors.

Outstanding scientist V. I. Vernadsky created a harmonious theory about the natural waters of the Earth. Zh. S. Sydykov, member of the NAS RK, wrote the following in his article [1], dedicated to the 150th anniversary of the genius scientist of the twentieth century: "In creating his numerous works on natural waters, he, like no one else before him, used all the vast material and all the preceding experience of science in a better and fuller way in this and related fields, including laws, confirmed by practice and theory."

The three following fundamental interrelated provisions on natural waters is the quintessence of his theory: 1. On the unity of natural (or ground) waters, 2. On the water cycle and the related origin of groundwater, 3. On the energy of natural waters. His following words can be an epigraph when considering the first problem: "All natural waters, wherever they are, are closely related and represent a discrete

whole" [2, p. 592]. In the theory of V. I. Vernadsky on natural waters, their internal unity is the main point. Therefore, he considered the water as a whole on a planet-wide scale and emphasized its diversity and location in the earth interior and he also emphasized that ... "In the history of the Earth, natural water "stands apart" among all other terrestrial elements and that there is no natural body that could be compared with its influence on the course of the main, most imposing geological processes" [2, p. 16].

The cycle of natural waters on the Earth is a form of existence and dialectically this process is not somehow closed, and with each new cycle of this process some new transformations take place in the environment. One of the show of the unity of natural waters in the hydrogeological cycle is the interrelation between surface water and groundwater, determining the mutual conditioning of their regime, the dependence of their characteristics on each other [3,4]. The dynamics and magnitude of the groundwater recharging through the aeration zone is related to the difficulty in determining the water balance components, which led the hydrologists to carry out full-scale field investigations because the hydrogeological and hydrological information was insufficient. Therefore, in the 1970s and 1980s field and experimental research in various parts of the Soviet Union was widely developed, and mathematical simulation methods came into using [5-9].

Water exchange in the underground hydrosphere is a process that characterizes the transfer (movement) of natural waters in isolated systems (geological structures) or in their parts, and also from one system (part) to another. This process begins with the groundwater inflow to the aquifer system (or part of it), moving inside and moving out of it into adjacent systems (discharging). Thus, the characteristic components of water exchange in the hydrogeological structure are recharging and discharging of groundwater, which is to say groundwater runoff.

Water exchange in a natural environment is a somewhat arbitrary concept. In recent millennia, mankind has been actively invading the natural surroundings by deforesting, increasing the tilth land for growing crops and obtaining food, in a word, its influence on nature turned out to be so powerful that it led to a change in various elements of the environment, which ultimately affected primarily soil and vegetation cover and deterioration of water exchange conditions.

The water exchange study is carried out in the current period already taking into account the human impact on the natural environment, that have occurred. The variety of natural and anthropogenic factors that determine the formation of the quantity and quality of groundwater, the features and intensity of water exchange, determine the very complex nature of the space-time hydrogeological models of the structures studied.

The water exchange intensity is determined by the mobility of natural waters when moving within the system or part of it. It depends on the boundary conditions, the spacial distribution of parameters and the size of the geofiltration flow. The water exchange intensity integrally reflects the entirety of the listed factors. The quantitative indicators of the water exchange intensity may be the rate of groundwater flow, the groundwater discharge and the duration or rate of water exchange, which is determined by the ratio of the groundwater capacitive resources to the flow rate and reflects the possible conditional time for substitution of groundwater contained in the isolated volume of the system. Hence the following units of measurements are selected: m/day × m^3/year; Flow rate in modular form - m^3/(day×km^2), m^3/(year×km^2); rate of water exchange - years.

Different types of water exchange geosystems can be distinguished depending on the research objectives, the nature of the boundary conditions and the structure of the geofiltration medium in the underground hydrosphere. That part of the underground hydrosphere, which is most closely connected with external surface factors of formation, recharging and discharging of groundwater (the zone of intensive water exchange) is of greatest interest for economic use. As it is known, groundwater in natural conditions is the most dynamic component of the lithosphere, and if the ecosystem approach is used, then it is also a component of the ecosystem. Due to its ubiquity, water is also a unique and sensitive indicator of the ecosystem state. If it is in an equilibrium state and the negative factors affecting it are minimal, the ecosystem, taken as a whole, is functioning normally.

However, as a result of the intensification of the human impact on the environment, there are significant changes in the water exchange direction, when the waste of production processes are involved in the turnover, the conditions for the underrun of contaminated surface waters arise, which gradually leads to an increase in negative phenomena in the water-bearing geological environment itself. In this

regard, the consideration of those aspects of modern hydrogeology that relate to the most dynamic parts closely associated with surface factors, as well as individual parts of the underground hydrosphere, becomes a new area of studying the conditions for the groundwater formation. The term "water exchange", which was introduced into the hydrogeological literature by N. K. Ignatovich, B. L. Lichkov, F. A. Makarenko and other researchers, in our opinion, fully and capaciously reflects one of the main properties of natural waters and it has not lost its initial role as an indicator of the conditions for the formation of various types of groundwater.

The general orientation of the lateral water exchange in the water exchange basin is usually observed from the watersheds to river valleys. The degree of equivalence of the configuration and dimensions of river basins and their corresponding water exchange basins depends on the features of the geofiltration medium of the water exchange system, the territory morphostructure, in particular the depth of the cut and the structure of the river valleys of the river basins under consideration and adjacent river basins. Moreover, these conditions are mainly applicable to the uppermost hydrodynamic zone, the so-called active water exchange zone. For deeper horizons, especially artesian waters, the geological feature of the hydrogeological structure, the availability of well permeable reservoirs and the dense argillites dividing them is of paramount importance for water exchange.

Method of study. Conceptually, the diagram of the interrelation between individual elements of the water balance of the active water exchange zone can be represented in the form of the following flow diagram (figure 1).

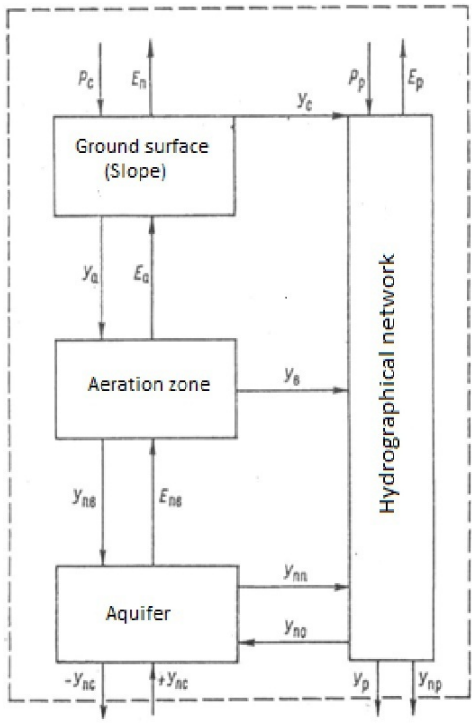

Figure 1 – The interrelation between surface water and groundwater in the hydrological and hydrogeological cycles.

Water balance elements Precipitations: P_l - on the land surface, P_w - on the water surface; evaporation: E_l - from the land surface, E_w - from the water surface, E_a - from the aeration zone, E_{gw} - groundwater (groundwater capillary outflow to the aeration zone); runoff: Y_r - total river, Y_s - slope (surface), Y_a - moisture runoff in the aeration zone (in some cases with the formation of temporary aquifers), Y_{ulgw} - surface runoff and runoff of the upper layer of ground water, Y_{gw} - moisture runoff in the aeration zone for groundwater recharging, Y_{uf} - underground flow into rivers, Y_{uo} - underground outflow of river water for groundwater recharging, Y_{gr} - groundwater runoff of the deep water exchange (minus - outflow, plus + + inflow), Y_{ur} - underflow runoff out of the river basin Arrows indicate the direction of movement of water and moisture, dotted line indicates the border of the river basin. The processes of moisture condensation are not taken into account in the diagram

However, the application of these methods in order to assess the interaction of surface water and groundwater is associated with the need for accurate measurements of all parameters of surface water movement on land, and especially in the channel part of river valleys, as well as in the upper hydrodynamic zone where the first ones flow from the ground surface of the groundwater. Often, in the absence of hydrological and hydrogeological parameters, measured during full-scale studies, it is very difficult to obtain precise quantitative values of this mutual influence.

In the 60-80s of the last century, the Hydrometeorological Service of the USSR and its subordinate Leningrad Hydrological Institute conducted throughout the country the studies of the surface water regime on the observational network and their scientific generalization. The result of this work was the publication of the "Surface Water Resources of the USSR" multi-volume edition, consisting of series: 1. Hydrological exploration degree, 2. Basic hydrological characteristics, 3. Surface water resources. Each

series consist of 20 separate volumes, some of which in turn include several issues. Two issues were published in Kazakhstan [10,11]. This monograph combines the materials of two series (the 2-nd and the 3-rd) on the dryland under consideration. And the volume 13 of the issue 1 describes the territory of Central Kazakhstan [12].

The study of the interrelation between surface water and groundwater is a central point in the theory of the formation of land natural waters, so the study of the hydrogeological conditions of any territory will not be complete unless their interrelation is taken into account.

Underground recharging of rivers, basic concepts and common patterns. Underground recharging of rivers consists of a process of the waters of springs, mochezinas running off into the rivers channels; these springs, mochezinas come out either on the surface, or in the bottom parts of the streamflows channels flowing into the main river channel. The amount of underground water entering the river is usually called an groundwater inflow (underground runoff). When assessing the total water balance of the river, this amount is taken as the underground component of the river runoff. At the same time, it is necessary to divide this runoff into so-called "basic", runoff from permanent aquifers and the component from the temporary aquifers, which is as a temporary groundwater inflow (runoff of the upper layer of ground water or soil runoff).

Runoff of the upper layer of ground water and soil runoff refer to the rapidly flowing part of groundwater that takes part in the recharging of rivers only during high water content periods (spring floods, rain floods), and it is usually completely stopped in the low streamflow period. This component of the groundwater runoff is often not taken into account, since the quantitative data on the measurement of these quantities is not available in regional studies and assessments of the water balance of the territories.

The main regularities of rivers recharging in various natural conditions are determined primarily by the discreteness of the showing of the interrelation of river water and groundwater. The latter is associated, on the one hand, with the regime of groundwater runoff in aquifers drained by the river at various hypsometric elevations, and, on the other hand, with the regime of river waters recharging at different positions of the river water level and the groundwater level regime.

At the same time, the levels of aquifers drainage caused by the location of the erosion base level in specific parts of the river valley are of crucial importance in the discreteness of the groundwater inflow. Each erosion base level corresponds to its drainage levels, which determine the limits of uniformity of the regime regularities and the degree of intensity of the underground water exchange.

In general, there are the following according to the drainage conditions within the river basins: the water-dividing sections of the surface watershed area where the permanent aquifers are not drained, but only the formation of a predominant surface slope runoff and the water infiltration for groundwater recharging; and part of the watershed, within which a permanent river system develops, where water exchange between the river and aquifers takes place.

Within the individual drainage levels the discreteness of the underground runoff of the so-called intensive (active) water exchange can also be associated with the location of underground watersheds, which determine the general direction of groundwater movement within the limits of underground watersheds. At that, two types of water objects are distinguished: with coincident and non-coincident surface and underground watersheds.

In terms of the number of drained aquifers, one and multi-layer systems for underground recharging of rivers can be identified, which also determine the discreteness of the groundwater inflow. In conditions of a single-layer system, the underground watersheds practically coincide with the surface watersheds and the boundaries of the latter determine the discreteness of the groundwater inflow of this level of drainage by the local hydrographic network.

In conditions of multi-layered underground recharging systems, the degree of discrepancy between the surface and underground watersheds increases, as a rule, for each subsequent deeper horizon. The degree of discrepancy between watersheds, especially the second and deeper drainable aquifers, should be determined at least roughly from the full-scale data on free and pressure levels of groundwater and from other hydrogeological, geomorphological and geological data. This is especially important in studies in mountain and karst areas, where positive results of work can be determined to a great extent by the objectivity of assessing the correspondence of surface and underground watersheds. The difficulty in determining the actual boundaries of the underground watersheds leads to the fact that in the calculations

of river runoff and underground recharging of rivers, the surface watershed area of the river is taken for the underground watershed.

The discreteness of the groundwater inflow within the boundaries of its formation under the influence of this drainage level can be associated with a change in the conditions and degree of hydraulic connection of river water and groundwater. Under the conditions of different hydraulic connection, the direction and water exchange of the river and the aquifers which it drains are dependent on the ratio of river water and groundwater levels in the areas situated near the river channel. The ratio of river water and groundwater levels is determined by the regime of groundwater runoff in the watershed and by the river's level regime and it depends on the morphological structure of the valley, the changes in hydrometeorological conditions in the river basin and it causes the corresponding patterns of intra-annual irregularity in the groundwater inflow, such as the regime of underground recharging of the river.

Method of study. Typification of the basic conditions for the interaction of river water and groundwater can be clearly seen in the diagram (figure 2), which shows the downcutting of the river channel with the water level position, as well as the level surface position. The type of regime of the underground recharging of rivers depends on the ratio of groundwater inflow discharges: Q_r - before the rise of the river water level before the high water (flood), Q_u - the maximum value of the groundwater inflow during the flood period, Qd - with the decline of high water, when the river transits to predominantly underground recharging (the beginning of the low water season).

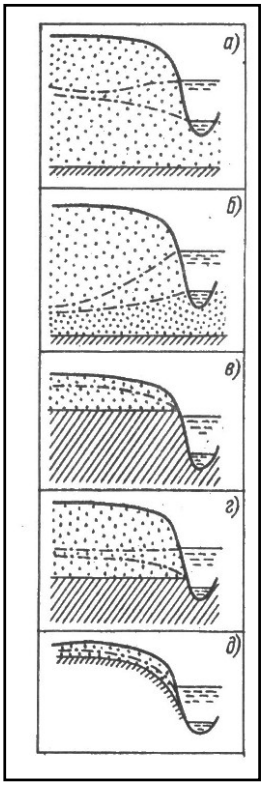

Figure 2 – Typification of the basic conditions for the interaction of river water and groundwater:

a - full hydraulic connection of the aquifer with the river upon the onshore regulation, *b* - full hydraulic connection upon the underground outflow, *c* - lack of hydraulic connection, *d* - periodic hydraulic connection upon high river water levels, *e* - weak hydraulic connection (for example, with a mountain river and etc.)

According to the ratio of these discharges, the following main types of underground recharging of rivers can be identified (figure 2). The type of the descending (free) underground recharging of the river (see figure 2*a, b*) is typical for the following conditions: 1) lack of hydraulic connection of rivers with aquifer; 2) under the conditions of hydraulic connection, when backing of groundwater by the river waters in the near-river zones has a weak or short-term effect (see figure 2*c, d*).

The type of retained underground recharging of the river (figure 2 *c, d*) is typical for conditions when, during hydraulic connection of the river with the aquifer, the rise in the river water level leads to the backing of groundwater in the near-river zone and the development of so-called bank storage, which is the river water filtration into the banks at the ascending stage of high water (flood) and their return to the rivers with the decline of high water.

The intra-annual irregularity in the groundwater inflow reflects the dynamics of groundwater runoff in the watershed, determined by the uneven recharging of groundwater. Due to the significant overregulation of the groundwater runoff, the maximum discharges of the groundwater inflow may be somewhat delayed relative to the flood peak. (see figure 2*a*) or coincide with the end of the flood, when the river transits to predominantly underground recharging (see figure 2*b*).

In conditions of hydraulic connection of the river with aquifers, when during high water periods (floods) there are synchronous and definitive changes in the level of river water and groundwater in the riverain zone or the rise in the level of the latter occurs more intensively, there will also be a descendent movement and recharging of the river.

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The practice of studies of groundwater runoff and underground recharging of rivers indicates that when using the methods of the listed groups, the most correct solution can be obtained only on the basis of the using the results of a joint analysis of hydrometeorological and hydrogeological information on the water regime and the natural features of the studied object. Thus, the connection of surface water and groundwater as a determining factor in the formation of annually renewed groundwater resources in arid regions is a very important component that allows for the assessment of groundwater resources in Kazakhstan.

Water exchange in natural aquifer system serves as a qualitative and quantitative basis for solving various hydrogeological and hydroeconomic problems of a research, methodological and applicable nature. The diversity of natural water exchange geosystems predetermines the diversity of the space-time forms, intensity and scale of water exchange. The complexity of the water exchange structure, imposing different space-time elements on each other, are determined depending on the problem being solved and the specific hydrogeological conditions of the object. Depending on the scope of the study, individual forms may be excluded from consideration or simplified in space and time or water exchange elements. The water exchange research strategy should be based on a system of various scales models, including detailed site models, local fragment models and regional models that provide background research for the target solution. The following time periods can be investigated: days, seasonyears, long-time average annual periods of time.

Key (reference) sites of detailing are important in the construction of regional models, which allow to identify and study the basic parameters and patterns of water exchange that determine the principles and details of extrapolation of their reference values in time and space. Such a combination of various scales models allows to solve more objectively the questions on the permissible degree of the model simplification and the corresponding errors of the solutions obtained. The questions of permissible averaging of individual parameters, choice of methods of study, scopes and types of research are also solved on the basis of the carried out evaluation of the optimal degree of space-time schematization.

Three following areas can be distinguished in the development of the theory of the groundwater formation in Kazakhstan: 1) development of methods for studying and mapping the processes of groundwater resources formation; 2) general theoretical problems of regional distribution of groundwater and generalizations of their formation and accumulation; 3) detailed study of individual regions and the most promising and water-rich types of groundwater. The first two directions made it possible to create a complex of hydrogeological maps and to prepare a basis for showing the most important hydrogeological, geomorphological, climatic and other features of the accumulation of the water mass of aquifers and complexes of hydrogeological structures.

Based on the results of these studies, a whole series of survey hydrogeological maps was prepared and published for the first time for the arid territory of Kazakhstan, a list of which we have shown in the list of cited references.

The maps show the variety of conditions for the groundwater resources formation on the territory of the republic, the presence of numerous promising structures and aquifers, and the regularities in the groundwater deposits distribution have been assessed and clarified. These works have disproved the mistaken opinion that Kazakhstan's subsurface resources are poor with fresh water and at the same time revealed 70 artesian basins, numerous groundwater flows with huge so-called "age-long" (7.5 trillion m^3) and annually renewable (48 billion m^3) resources, and established their operational capabilities in the volume of 1960 m^3/s.

The results of the hydrogeological survey subsequently showed that this approach greatly facilitated the identification and exploration of new groundwater deposits for various needs, significantly increasing their effectiveness. Thus, the widespread use of groundwater for water supply to the population and various economic sectors has become yet another confirmation that Kazakhstan's subsurface resources contain a sufficient number of pathogen-free groundwater that can become a reliable reserve of the country's water resources in the absence of the necessary interstate agreements and joint legal documents governing their sharing.

A brief outline of the history of the development of the groundwater formation theory in Kazakhstan shows that it is constantly developing and is filled with new content that takes into account not only the specific features of Kazakhstan's territory, but also the global trends that take into account the ecological component, as well as global processes in the climate change and the water resources cycle on the Earth. Scientists and specialists from Kazakhstan's neighbouring countries note a consistent and systemic approach, which is proposed to be solved taking into account the mutual interests by the Kazakhstan party, while de jure an agreement is still not reached in interstate relations on the use of transboundary water resources. In this issue, Kazakhstan advocates for the use of a world or at least a European practice of water apportioning in each drainage basin. It is sufficiently well developed and adherence to its provisions would help to avoid conflict situations and contribute to the preservation of ecological stability in these transboundary areas.

The groundwater formation problem includes a number of controversial and contradictory concepts and provisions, interpreted in different ways. For example, there is no unambiguous interpretation of the problem of the primary source of the Earth's hydrosphere. Either it appeared simultaneously in the period of particles accretion from a dust-gaseous nebula, among which water was also present in the form of ice crystals. Either it was separated from the protoplanetary substance itself over a long period of terrestrial substance differentiation over a certain period of the Earth's life.

A number of controversial questions concern the definition of the subject of hydrogeology, which was often associated in the past with hydrology, the science of the land waters. Later, when as a result of drilling deep wells, hydrogeologists discovered groundwater in super-deep wells and could determine their absolute age, gave an explanation of their chemical composition and the water-soluble substances, incl. gases contained in it, hydrogeological science has acquired all the necessary attributes as an independent science on the Earth's underground hydrosphere. Thus, hydrogeology is now an integral part of the series of Earth sciences, entering into a number of fundamental sciences.

Conclusions. Thus, it can be stated that the regional assessment of the interaction of river waters and groundwater requires the use of additional hydrogeological and hydrological information obtained on normal profile and gauging stations. For arid regions an estimate of the underground outflow of river waters is very important, since most of the time of the year the rivers are recharged by the underground aquifers. But, during the onset of the so-called "dry time", when the air temperature begins to rise and atmospheric precipitation ceases, the rivers transit to underground recharging by discharging them into deep reaches. This situation has a very positive effect on the saving of river biota and the ecosystem as a whole.

It also follows from the above that in the arid conditions of Kazakhstan the underground outflow of river waters plays its positive role in the general cycle of water resources. Therefore, when using river water and groundwater, it is necessary to constantly monitor the development of these processes through monitoring and take timely measures to prevent excessive withdrawal of both the surface and underground

component of the water flow of any territory. In the typification of underground outflow of river waters, the following are distinguished: a). Temporary (seasonal) outflow. This type is characterized by coastal infiltration, as well as periodic losses to the karst cavities. b). Constant outflow. The groundwater recharging from the river channel with the occurrence of aquifers below the river level. It is a very characteristic phenomenon for rivers in countries with arid climate, as well as for some mountain rivers and areas where karstic rocks are developed. This type is also characteristic for river valleys, which cut through inclined water-permeable layers in their geological structure and losses of river water occur in one bank, along the slope of the aquifer. But the underflow runoff is the most frequent form of river water outflow. Almost all major rivers of Kazakhstan for a large part of the valleys have a constant underflow runoff.

As researches have shown, the initial hydrological and hydrogeological information serves as a basis for an objective assessment of the features of the interrelation of surface river water and groundwater. The list of basic hydrogeological information consists of the following data:

1. the general characteristic of the hydrological exploration degree of the territory is needed;
2. the characterization of the drained aquifers distribution according to the lithologic and stratigraphic characteristics and general physical and geographical conditions;
3. the information on the location of surface and groundwater watersheds in different parts of the watershed area of the main river and its tributary streams;
4. the characteristic of underground recharging of rivers in separate sections of the river basin with respect to the number of drained aquifers and the degree of their participation in the formation of an underground tributary stream.
5. the information on the features of the hydraulic connection between river waters and aquifers drained by the river;
6. the characterization of the intra-annual irregularity of groundwater runoff in the watershed, primarily in relation to its discreteness, depending on the lithologic and stratigraphic features of the drained aquifers and their water regime;
7. the information on the relationship between the amplitudes and rates of changes in the groundwater level in the near-river zone and river waters to determine the possibility of bank storage developing and calculating the dynamic amplification factor of the groundwater inflow to the river under conditions of the bank storage;
8. the quantitative characteristics of the coefficients of intra-annual dynamics of groundwater runoff in watersheds and groundwater inflow to the rivers based on the results of full-scale observations, by hypothesis or established by expertise on the basis of analysis of materials obtained in previous studies.

When generalizing hydrogeological information for calculations of the groundwater inflow to the rivers, it is advisable to use the principles and methodology of schematization of hydrogeological conditions, which are usually used in modeling in hydrogeology [9, 13, 32, 33, 38].

When assessing the groundwater inflow to the rivers, the hydrological information is used for the solution of the following main tasks:

1. the general characteristics of the hydrological exploration degree of the water body;
2. the determination of the hydrographic network structure and the connection of its structure with the discreteness of the groundwater inflow to the rivers at various levels of drainage of aquifers and complexes;
3. the establishment of the compliance of the hydrometrical section location with data on the low runoff of the actual discreteness of interaction between river water and groundwater within the study area;
4. the determination of typical water discharges in the period of low runoff at representative hydrometrical sections in order to calculate the total groundwater inflow to the rivers within the watershed above the measuring section line;
5. the obtaining of regime data on water levels in rivers under conditions of hydraulic connection between river water and groundwater in order to assess the intra-annual irregularity in the groundwater inflow to the rivers and in order to determine the possible degree of bank storage development in years of different water content.

General information on the river basins of the study area, climatic data, characteristics of the regime of surface water and groundwater, the hydrological regime of rivers and the river basins water balance, the minimum runoff and other data necessary for calculations of water regime elements. A great help in

collecting hydrological information can be provided by new “Water resources of Kazakhstan: estimation, forecast, management” monographs, consisting of 21 volumes and published in 2012 by the Geography Institute of the RK. Two of which were used by us when writing this report [32, 33].

In conditions of weak hydrological exploration degree of the territories and the complex hydrogeological structure of the groundwater basins, it may be necessary to carry out occasional measurements of water discharge at key river stations during the periods of low water season, over which it will be possible to determine the design characteristic calculation. N.S. Ratner developed a very acceptable method for calculating the characteristics of the groundwater inflow to the rivers according to data of direct measurements of the water discharge of rivers during the periods of low water season [39].

Recommendations for improving the accuracy of occasional measurements of water discharge in the plain and mid-mountain areas, as described in the works of the SHI (State Hydrological Institute), are very useful [17, 19, 23-25, 39]. Details of the organization and carrying out of hydrometrical surveys (content, periods and methods of conducting hydrometrical operations, primary processing of the results obtained) are considered in methodological recommendations [17, 39, 41]. Methods of carrying out experimental work and processing their results are described in vast domestic and foreign literature. Among others there is a significant number of publications highlighting the features of the methodology for conducting the testing for groundwater inflow in the study of the conditions of the interrelation between the groundwater and surface water [42].

Concluding consideration of the problem of the interrelation between the surface water and groundwater, it is necessary to highlight its importance both from the scientific and from the practical aspects. In this regard, it is worth recalling that little attention was paid to this problem in previous years. For example, publications on the surface runoff of the rivers of Kazakhstan are quite sufficient by now, which can not be said about the hydrogeological aspects of the interrelation between the surface and underground runoff. The authors of this report found only a few works devoted to this problem [43-48]. Studies in this important area should be expanded.

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ЖЕР ҮСТІ ЖӘНЕ ЖЕР АСТЫ СУЛАРЫ ЕСЕБІНЕН ҚАЗАҚСТАН АУМАҒЫНДА ЖЕР АСТЫ СУЛАРЫНЫҢ РЕСУРСТАРЫН ҚАЛЫПТАСТЫРУ ЗАҢДАРЫ

Аннотация. Гидрогеологиялық құрылымдарды зерттеу және жер үсті және жер асты суларының арасындағы қатынастарды орнату. Түрлі геоморфологиялық аймақтардан жер үсті және жер асты сулары арасындағы байланыс көрсетіледі; Бұл аймақтар таулы, тау бөктерінде және тіпті рельефте ұсынылған. Жер асты суларының қалыптасуын реттейтін заңдар және оларға өзен жүйелерінің үстіңгі ағынының әсері белгіленді. Бұл қатынас құрғақ климаттық жағдайда экожүйенің экологиялық тұрақтылығын сақтауға, гидрогеологиялық жүйелердің су ағындарын өзен алқаптары шөгінділерінің аллювиальды шөгінділерімен қайта бөлуге көмектеседі. Осы кезеңде өзен алқаптары мен үстіңгі сулы қабаттың аллювиалды шөгінділерінің жер асты сулы қабаттары арасындағы су алмасуды сақтау су алмасу арқылы қоршаған ортаның тұрақты жағдайын сақтауға мүмкіндік береді. Бұл жұмыста иллюзивті мақсаттар үшін активті су айырбастау аймағының су балансының жекелеген элементтері арасындағы байланыстың блок-схемасы (жауын-шашын, аэрация аймағындағы судың енуі, ең алдымен сулы қабаттың бетіндегі, көлденең далалық және жер асты дренаж және т.б.) берілген. Жерасты суларының ағынын қалыптастырудың ерекшеліктерінде өзен мен жер асты суларының арасындағы қарым-қатынастарды сандық бағалауды зерттеу және жүргізу әдіснамасы бөлек беріледі.

Түйін сөздер: жер үсті суларының ағысы мен табиғи ағыны, табиғи (жыл сайын жаңартылатын) ресурстар.

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ЗАКОНЫ ФОРМИРОВАНИЯ РЕСУРСОВ ПОДЗЕМНЫХ ВОД НА ТЕРРИТОРИИ КАЗАХСТАНА ЗА СЧЕТ ПОВЕРХНОСТНЫХ И ПОДЗЕМНЫХ ВОД

Аннотация. Изучение гидрогеологических структур и установление связи между поверхностными речными и подземными водами. Показана взаимосвязь между поверхностными и подземными водами разных геоморфологических регионов; эти регионы представлены горным, предгорным и ровным рельефом. Установлены закономерности формирования подземных вод и влияние на них поверхностного стока речных систем. Такое соотношение помогает поддерживать экологическую устойчивость экосистемы в засушливых климатических условиях, перераспределяя водный сток гидрогеологических систем с водоносными горизонтами аллювиальных отложений речных долин. В этот период сохранение водообмена между подземными водоносными горизонтами аллювиальных отложений речных долин и вышележащими водоносными образованиями позволяет поддерживать стабильное состояние окружающей природной среды за счет водообмена. Представлена блок-схема взаимосвязи между отдельными элементами водного баланса активной зоны водообмена (осадки, инфильтрация воды в зоне аэрации, в первую очередь с поверхности водоносных горизонтов, наклонные полевые и подземные стоки и т. д.) для иллюстративных целей в этой работе. Отдельно дается методика изучения и проведения количественной оценки взаимосвязи между рекой и подземными водами в особенностях формирования стока подземных вод.

Ключевые слова: поверхностный сток и сток подземных вод, природные (ежегодно возобновляемые) ресурсы.

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REFERENCES

[1] Sydykov Zh.S. The main provisions of academician V.I. Vernadsky's theory on natural waters // Proceedings of the NAS RK. Series of geology and engineering sciences. 2013. N 1. P. 84-89.

[2] Vernadsky V.I. Selected works. Vol. IV, the second book. M., 1960. 653 p.

[3] Shestopalov V.M., Sitnikov A.B., Lyalko V.I., et al. Methods of studying water exchange // In the book "Water exchange in hydrogeological structures of Ukraine". Kiev: Nauk. dumka, 1988. 272 p.

[4] Shestopalov V.M., Sitnikov A.B., Lyalko V.I., et al. Water exchange in natural conditions // In the book "Water exchange in hydrogeological structures of Ukraine". Kiev: Nauk. dumka, 1989. 288 p.

[5] Antontsev S.N., Epikhov G.P., Kashevarova A.A. System mathematical simulation of water exchange processes / Ed.-in-chief P. Ya. Polubarinova-Kochina. Novosibirsk: Nauka, SB (Siberian Branch) of the USSR AS (Academy of Sciences), 1986. 215 p.

[6] Epikhov G.P. Mathematical simulation of planned filtration in interrelation with river runoff and its implementation // Water resources. 1980. N 2. P. 35-44.

[7] Sokolov V.G. Mathematical formulation of the problems for interaction of surface water and groundwater // "Problems of hydrology" collected volume. M.: Nauka, 1976. P. 128-139.

[8] Vsevolozhsky V.A., Dyunin V.I., Gurova N.N. Studies of artesian structures groundwater runoff // Interaction of surface and groundwater runoff. 1976. Issue 4. P. 45-57.

[9] Gavich I.G. Theory and practice of applying mathematical simulation in hydrogeology. M.: Nedra, 1980. 358 p.

[10] Resources of surface waters of the USSR. Vol. 12. Lower Volga region and Western Kazakhstan. Issue 3. Aktobe region. L., 1966. 515 p.

[11] Resources of surface waters of the USSR. Vol. 12. Lower Volga region and Western Kazakhstan. Issue 2. Ural-Emba region. L., 1966. 515 p.

[12] Resources of surface waters of the USSR. Vol. 13. Lower Volga region and Western Kazakhstan. Issue 1. Central Kazakhstan. L., 1966. 515 p.

[13] Shestopalov V.M. Methodological aspects of studying water exchange in hydrogeological structures // Water exchange in hydrogeological structures of Ukraine. Kiev: Naukova Dumka, 1988. 272 p. (P. 8-52).

[14] Kudelin B.I. Principles of regional assessment of groundwater natural resources. M.: MMU (Moscow Mining University), 1960. 344 p.

[15] Groundwater runoff in the territory of the USSR. Under the editorship of B. I. Kudelin. MMU, 1966. 303 p.

[16] The runoff of Kazakhstan's groundwater. Alma-Ata, 1964. 86 p.

[17] Hydrometrical assessment of the interaction of river water and groundwater (temporary methodological recommendations). L.: SHI, 1973. 77 p.

[18] Regional assessment of underground recharging of the USSR rivers // Proceedings of the SHI. 1968. Issue 154. 175 p.

[19] Popov O.V. Use of hydrological information in forecasting groundwater resources // Methods for analysing and processing hydrogeological data for forecasting groundwater resources. Tallinn: the ESSR AS, 1984. P. 85-91.

[20] Karasev I.F. River hydrometry and water resources accounting. L.: Gidrometeoizdat, 1980. 310 p.

[21] Kritsky S.N., Menkel M.F. Methodical base of water management balances construction // Proceedings of the Hydroproject. 1964. Collected volume 12. P. 29-62.

[22] Investigation of underflow runoff in water balance studies (methodological recommendations). L.: SHI, 1968. 42 p.

[23] Methodical instructions of TAHEM (Territorial Administration for Hydrometeorological and Environmental Monitoring). N 89. River basins water balances analyses. L.: Gidrometeoizdat, 1974. 96 p.

[24] Methodical instructions of TAHEM. N 90. Channel water balances analyses. L.: Gidrometeoizdat, 1977. 103 p.

[25] Methodological recommendations on accounting for the economic activity impact on the small rivers runoff in hydrological calculations for hydroeconomic design. L.: Gidrometeoizdat, 1986. 167 p.

[26] Kudelin B.I. To the method of determining the underground recharging of rivers // Reports of the USSR AS. 1950. Vol. 52, N 1.

[27] Kudelin B.I. Coastal regulation of surface runoff // Reports of the USSR AS. 1950. Vol. 21, N 1.

[28] Makarenko F.A. On underground recharging of rivers // Proceedings of the LGP (laboratory of hydrogeological problems) named after F. P. Savarensky, member of the USSR AS. 1948. Vol. 1.

[29] Kudelin B.I. Groundwater runoff in the territory of the USSR. M.: MMU Publishing House, 1966. 303 p.

[30] Amusya A.Z., Ratner N.S. To the territory zoning under the conditions of interaction of surface water and groundwater in the water balances analyses // Water resources. 1985. N 1. P. 47-56.

[31] Water resources of Kazakhstan (Surface and groundwater, current state). Reference book. Almaty: "Gylymм" SRC, 2002. 596 p.

[32] Water resources of Kazakhstan: estimation, forecast, management. Group of authors. Vol. VII, book 1. Almaty, 2012. 684 p.

[33] Water resources of Kazakhstan: estimation, forecast, management. Group of authors. Vol. VII, book 2. Almaty, 2012. 360 p.

[34] Sydykov Zh.S., Mukhamedzhanov M.A. Underground water and chemical runoff of the active water exchange zone of the Peri-Caspian Depression // Proceedings of the NAS RK. Geological series. 2006. N 5. P. 77-84.

[35] Sydykov Zh.S., Mukhamedzhanov M.A. Groundwater and salt runoffs of the Lake Balkhash basin // Proceedings of the NAS RK. Geological series. 2009. N 6. P. 52-56.

[36] Formation of groundwater runoff in the territory of Kazakhstan. Group of authors. Alma-Ata: Nauka, 1970. 147 p.

[37] Sydykov Zh.S. Groundwater runoff in the territory of Aktobe Semirechie // Proceedings of the NAS RK. Series of geology and engineering sciences. 2012. N 4. P. 48-49.

[38] Minkin E.K. Interrelation of groundwater and surface waters and its importance in solving some hydrogeological and hydroeconomic problems. M.: Stroyizdat, 1973. 103 p.

[39] Ratner N.S. The use of hydrometrical information for the regional assessment of the interaction of river water and groundwater // Proceedings of the SHI. 1981. Issue 272. P. 10-24.

[40] Materials of the interdepartmental workshop on the method of hydrometrical assessment of groundwater runoff to the rivers (Valdai, June 15-19, 1965). Valdai, SHI, 1966. 230 p.

[41] Petrov G.N. Low streamflow runoff and its study // Proceedings of the Kazan branch of the USSR AS. Ser. Energy and Water Management. 1956. Issue 1. 144 p.

[42] Shestakov V.M. Groundwater dynamics. M.: MMU Publishing House, 1973. 327 p.

[43] Grinberg S.V., Osipova A.N. On underground recharging of mountain rivers of the Zailiysky Alatau northern slope // Proceedings of the Kazakhstan SSR AS. Geological series. 1963. N 5. P. 89-95.

[44] Shlygina V.F. Groundwater runoff from the Zailiyskiy Alatau northern slopes and its role in the alluvial cone groundwater recharging // Proceedings of the Kazakhstan SSR AS. Geological series. 1964. N 4. P. 48-62.

[45] Dzhakelov A.K. To the methodology for determining the groundwater deep runoff formed in the mountain-folding regions (for example, the Zailiysky Alatau) // Proceedings of the NAS RK. Geological series. 2007. N 6. P. 73-86.

[46] Overview. Water resources of Kazakhstan in the new millennium. Almaty, 2004. 132 p.

[47] Development of water balance in the basins of rivers Big and Small Uzeni; Scientific report of the Uralvodproekt LLP. Uralsk, 2002. Book 2. 263 p.

[48] Mukhamedzhanov M.A., Sagin Jai, Kazanbaev L.M., Rakhmetov I.K. Relation between surface water and groundwater as the factor for formation of groundwater renewable resources on the territory of Kazakhstan // "Izvestiya" National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 5, N 431. P. 15-17. https://doi.org/10.32014/2018.2518-170X.1 ISSN 2518-170X (Online). ISSN 2224-5278 (Print).

[49] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

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ISOTOPE MASS SPECTROMETRY APPLICATION FOR THE ABIOGENIC ALCOHOLS DETECTION IN GRAPE WINES

Abstract. Practice shows, that a single indicator д^{13}C ‰, characterizing the ratio of stable isotopes of ^{13}C/^{12}C carbon, in some cases is not enough to detect alcohol in alcohol wines of an innocent origin, especially when abiogenic alcohols are introduced into the product. The instrumental base for obtaining characteristics of isotopes elements of ethanol molecules was Delta V Advantage of the Thermo Fisher Scientific (USA) mass spectrometer complex , which provides a precise analysis of prevalence ratios of ^{13}C/^{12}C, ^{18}O/^{16}O, D/H isotopes. It has been established that the isotope characteristics of abiogenic alcohol oxygen, obtained by hydration of ethylene significantly differ from this index for all alcohols of plant origin. The isotope characteristics of most vegetable alcohols oxygen fit within the range д^{18}O‰ from 5.38‰ to 16.29‰, and only for beetroot alcohol the numerical values are somewhat lower, namely: 1.66–2.05 ‰. At the same time, the value of д^{18}O‰ in abiogenic ethanol has a negative sign and amounts to minus 14.21 ‰ – minus 15.20 ‰. These significant differences allow us to use this indicator to establish the nature of the used alcohols – vegetable or abiogenic origin. Analyzing the indicator дD ‰, it can be noted that the hydrogen of the abiogenic alcohol is noticeably "heavier" than the hydrogen, contained in the alcohols of vegetable origin and is minus 140‰ – minus 153‰ against minus 213‰ – minus 266‰. Using the values obtained, 24 samples of table wines were examined. Two samples had a value of д^{13}C minus 28.22‰ and minus 28.41‰, respectively, д^{18}O minus 1.0‰ and minus 0.76‰, which indicates the presence of abiogenic alcohol in the product. "Heavy" hydrogen дD (minus 172.66‰) and дD (minus 169.43‰), not characteristic for alcohols from plant raw materials, only confirm the conclusion. Similar studies have been conducted for liquor wines. Thus, by measuring the isotopic characteristics of the three elements of alcohol molecules – carbon, oxygen and hydrogen, the presence of alcohols of abiogenic origin can be detected with high degree of certainty in wines.

Keywords: wine, beverage identification, isotope mass spectrometry, wine ethanol, abiogenic alcohols, isotope ratio of ethanol molecules elements.

Introduction. Currently, the world produces a wide range of alcoholic drinks on grape and fruit raw materials. The main types of wine products from grapes are wine, liqueur (special) wines, sparkling wines, flavored wines, wine drinks, as well as alcoholic drinks above 37.5% - grape vodka, brandy, cognac, armagnac, etc.

To control the quality and authenticity of wine production, various methods of analysis are used. Normed indicators are defined in each batch of products, and these quantities are set in national and interstate standards of the type "general technical conditions". However, the fulfillment of the requirements of standards of this type ensures only confirmed conformity of the product to a certain species, characterizes its commercial properties and can't guarantee its authenticity.

In case of doubt the expert, he has the right to apply national and interstate standards of the form "identification". The most informative among them are the standards developed in recent years, based on the use of instrumental methods of analysis. These include, first of all, methods, based on the principle of isotope mass spectrometry.

This method showed high efficiency in determining the authenticity of grape wines. It is known that the most common way of falsification of this product type to introduce alcohols of an innocent origin after diluting the wine with water to provide the necessary conditions for alcohol.

Also, the introduction of cane and beet sugars, and, in addition, corn glucose-fructose syrup in diluted wort, followed by fermentation to obtain the necessary alcohol fermentation. In any case, exogenous alcohols appear in the wine after these operations, which is prohibited by law. Their presence can be detected using the method of isotope mass spectrometry [1-6].

Thus, the determination of carbon characteristics of native ethanol, contained in natural wines and cognacs ($д^{13}C$), which is usually in the range from minus 26‰ to minus 29‰, allowed to reveal the introduction of alcohols of an innocent origin, as they have values different from grape ethanol, namely: from minus 11‰ to minus 25‰. However, over time, falsifiers found a loophole in the method, adding to the alcohols from botanical origin an "abiogenic alcohol" that has isotope characteristics of carbon $д^{13}C$ from minus 32‰ to minus 35‰.

Thus, using the data isotopic characteristics unscrupulous manufacturers by adding alcohol to abiotic alcohols to vegetable spirits of non-grape origin, obtained blends with the desired characteristics $д^{13}S$ from minus 26‰ to minus 29‰ [7-10].

Given that the use of abiogenic alcohol is strictly forbidden in the production of food products because of its high toxicity, the problem goes beyond the control of authenticity and goes into the sphere of security.

There are cases of application of abiogenic alcohol not only for falsification of wine production, but also in the production of vodka, alcoholic drinks, and other types of alcoholic drinks. Thus, the use of abiogenic alcohol has recently taken a dangerous scale, which requires adequate control measures. For this, it is necessary to make fuller use of the advantages that the method, based on the principle of isotope mass spectrometry possesses.

As already mentioned, a single indicator $д^{13}C‰$, characterizing the ratio of stable isotopes of $^{13}C/^{12}C$ carbon, in some cases is not enough to detect alcohol in alcohol wines of an innocent origin, especially when abiogenic alcohols are introduced into the product.

Abiogenic alcohol is generally obtained by hydrating ethylene with steam under pressure in the presence of a catalyst. Given that in the molecule in addition to carbon atoms of the alcohol also includes oxygen and hydrogen, it can be assumed that the relationship isotope $^{18}O/^{16}O$ and D/H can be significantly different from the relationship of oxygen and hydrogen isotopes alcohols of plant origin. Indeed, the oxygen of the technical water involved in the reaction for obtaining abiogenic alcohol is much easier than the oxygen of the aqueous component of plant raw materials [11-24].

Methods. The research objects were alcohols of various origins, table wines, liqueur wines. The measurements were carried out according to the "Method for Measuring the Isotope Ratios of Carbon, Oxygen, Hydrogen Ethanol to Detect the Presence of Synthetic Alcohol in Alcohol Products, as well as in Alcohol-Containing Food Flavors by Isotope Mass Spectrometry" (Certificate of Attestation No. 205-48/RA.RU.3111787- 2016/2017, FZ.1.31.2017.28360).

The instrumental base for obtaining characteristics of the isotopic composition of ethanol molecules elements was the Thermo Fisher Scientific (USA) mass spectrometer complex Delta V Advantage, which provides a precise analysis of the prevalence ratios of $^{13}C/^{12}C$, $^{18}O/^{16}O$, D/H isotopes.

Carbon isotope characteristics were measured relative to the international V-PDB comparison. VPDB - as an international standard, the PDB standard is adopted, which is the isotope composition of the calcium carbonate carbon of the Belemnitella Americana fossil of the late Cretaceous period from the PDB formation (South Carolina, USA). The international standard PDB is characterized by a homogeneous isotopic composition. Currently, the Vienna equivalent of the PDB-VPDB is used as an international standard.

The isotope characteristics of oxygen and hydrogen were measured relative to the international comparison model VSMOW2. VSMOW2 is the Vienna Standard Mean Ocean Wat2.

The obtained ratios of carbon isotopes ($^{13}C/^{12}C$), oxygen ($^{18}O/^{16}O$) and hydrogen (D/H) were determined in ‰, using the software of a mass spectrometer, using formula

$$X\left(\delta^{13}C_{VPDB}, \delta^{18}O_{VSMOW2}, \delta D_{VSMOW2}\right) = \frac{\left(R_{sample} - R_{ref.}\right)}{R_{ref.}} \cdot 1000, \quad (1)$$

where R_{sample} – is the ratio of carbon isotopes ($^{13}C/^{12}C$) (oxygen ($^{18}O/^{16}O$), hydrogen (D/H)) in an ethanol sample; $R_{ref.}$ – the ratio of carbon isotopes ($^{13}C/^{12}C$) (oxygen ($^{18}O/^{16}O$), hydrogen (D/H)) in the reference gas CO_2 (CO, H_2).

Results and its discussion. The isotopic characteristics of д^{13}C, д^{18}O and дD ‰ of abiogenic alcohols, as well as alcohols from various types of plant raw materials, were studied. The results are summarized in table 1.

Table 1 – Isotope Characteristics of Ethanol Biophilic Elements of Different Origin

Sample name	Isotope Characteristics		
	д^{13}C, ‰	д^{18}O, ‰	дD, ‰
rectified ethyl alcohol: grape	-26.1 – -28.8	10.04–16.29	-200 – -240
fruit	-24.84 – -28.59	5.38–12.02	-213 – -239
grain	-24.80 – -25.87	10.27–13.57	-230 – -266
cane	-10.96 – -12.10	8.27–9.43	-215 – -230
corn	-13.84 – -15.10	10.87–11.98	-215 – -231
beet	-26.61 – -26.9	1.66–2.05	-270 – -290
abiogenic alcohols (hydration of ethylene)	-31.28 – -35.55	-14.21 – -15.20	-140 – -153

As can be seen from the data. presented in Table 1. the obtained results confirmed the assumption. that the isotope characteristics of oxygen of the abiogenic alcohol obtained by hydration of ethylene differ significantly from this index for all alcohols of plant origin. Most vegetable alcohols fit within the range of д^{18}O‰ from 5.38 to 16.29 ‰. and only for sugar beet the numerical values are somewhat lower. namely: 1.66–2.05 ‰. At the same time. the value of д^{18}O ‰ in abiogenic ethanol has a negative sign and amounts to minus 14.21 ‰ – minus 15.20 ‰. These significant differences allow us to use this indicator to establish the nature of the alcohols used - vegetable or abiogenic origin.

Analyzing the indicator дD ‰. it can be noted that the hydrogen of the abiogenic alcohol is noticeably "heavier" than the hydrogen. contained in the alcohols of vegetable origin and is minus 140 ‰ – minus 153 ‰ against minus 213 ‰ – minus 266 ‰.

Using the obtained values. 24 samples of table wines were examined. The results are summarized in table 2.

Analyzing the data of Table 2. we can conclude that all wines. except for samples 6. 12. 15. 19. are made without violation of technology. At the same time. sample 6 has values of д^{13}C and д^{18}O – minus 27.03 and 2.65 ‰. respectively. characteristic of beet alcohol or its mixture with grape ethanol. With a high probability. in the production of wine in grape must before or during fermentation process was introduced beet sugar.

The same can be said for the sample 9. which was apparently prepared by adding S4-type plants. corn glucose-fructose syrup. or cane sugar to the grape must. At least. the value of the indicator д^{13}C. equal to minus 17.45‰. speaks about this.

As for sample No. 15. having values of д^{13}C minus 28.41 ‰ and д^{18}O minus 0.76 ‰. and sample No. 18 with the values of д^{13}C minus 28.22 ‰ and д^{18}O minus 1.0 ‰. there is a fact of adding to product of abiogenic alcohol. "Heavy" hydrogen дD (minus 172.66 ‰) for sample No 15 and дD (minus 169.43 ‰) for sample No 18. not characteristic for alcohols from plant raw materials. only confirm the conclusion.

In accordance with the requirements of GOST 32715-2014 "Wine Liquors. Wine Liqueur of Protected Geographical Indications. Wine Liqueur of Protected Names of Origin Place. General Technical Conditions". liquors and distillates of grape or other vegetable origin are allowed to be added to liqueur wines. As it was said above. the legislation of the Russian Federation prohibits. the use of abiogenic ethyl alcohol for the production of food. including alcoholic products.

In the present work, when interpreting the results of measurements of the isotope characteristics of ethanol elements for liqueur wines. the numerical ranges characteristic of grape alcohols were used. as well as the isotope characteristics of ethanol extracted from plant raw materials of various origins and synthetic alcohol.

Table 2 – Table Wine Isotope Characteristics of Carbon. Oxygen and Hydrogen Ethanol

No	Sample name	Isotope Characteristics		
		д^{13}C.‰	д^{18}O.‰	дD.‰
1	White table dry wine	(-26.8)±0.2	11.56±0.25	(-239.79)±0.79
2	White table dry wine	(-27.19)±0.21	12.54±0.27	(-228.75)±0.81
3	White table dry wine	(-18.12)±0.18	8.76±0.25	(-230.01)±1.01
4	Red table dry wine	(-26.76)±0.2	10.76±0.29	(-215.42)±0.95
5	Red table dry wine	(-12.87)±0.15	8.32±0.27	(-237.31)±1.0
6	Red table dry wine	(-27.03)±0.15	2.65±0.25	(-282.01)±0.87
7	White table semidry wine	(-25.99)±0.21	9.91±0.25	(-217.09)±0.87
8	White table semidry wine	(-25.45)±0.18	10.32±0.29	(-230.34)±0.9
9	White table semidry wine	(-17.45)±0.2	9.02±0.27	(-217.09)±0.9
10	Red table semidry wine	(-26.01)±0.15	10.0±0.25	(-239.54)±0.89
11	Red table semidry wine	(-26.33)±0.2	9.89±0.29	(-213.65)±0.89
12	Red table semidry wine	(-26.60)±0.22	5.87±0.27	(-239.09)±1.02
13	White table semisweet wine	(-25.89)±0.2	10.21±0.27	(-235.21)±0.98
14	White table semisweet wine	(-10.16)±0.18	9.54±0.25	(-240.51)±1.0
15	White table semisweet wine	(-28.41)±0.2	(-0.76)±0.25	(-172.66)±1.0
16	Red table semisweet wine	(-26.75)±0.17	12.43±0.27	(-221.87)±1.01
17	Red table semisweet wine	(-10.90)±0.21	9.51±0.27	(-245.76)±0.9
18	Red table semisweet wine	(-28.22)±0.2	(-1.0)±0.25	(-169.43)±0.89
19	White table sweet wine	(-26.76)±0.2	12.98±0.29	(-211.33)±0.79
20	White table sweet wine	(-26.02)±0.18	9.87±0.27	(-225.54)±0.98
21	White table sweet wine	(-25.89)±0.19	11.43±0.29	(-209.89)±0.9
22	Red table sweet wine	(-27.02)±0.2	13.05±0.25	(-231.76)±1.0
23	Red table sweet wine	(-26.43)±0.2	10.76±0.25	(-220.19)±1.0
24	Red table sweet wine	(-15.42)±0.21	11.0±0.27	(-226.75)±1.01

The isotope characteristics of carbon, oxygen and hydrogen of ethanol isolated from liquor wines were measured. The data are presented in table 3.

As can be seen from the table. of the nine samples analyzed. only three samples (No. 1, No. 2 and No. 3) are prepared without a violation of technology. The isotope characteristics of carbon. oxygen and hydrogen of ethanol extracted from these samples are included in the numerical ranges established for alcohols of grape origin.

Table 3 – Isotope Characteristics of Carbon. Oxygen and Hydrogen Ethanol of Liqueur

Wines No	Sample name	Isotope Characteristics		
		д^{13}C.‰	д^{18}O.‰	дD.‰
1	Liqueur Wine	(-27.07)±0.18	11.09±0.3	(-227.91)±1.1
2	Liqueur Wine	(-26.65)±0.18	12.45±0.29	(-231.54)±1.09
3	Liqueur Wine	(-25.83)±0.2	10.54±0.29	(-230.54)±1.12
4	Liqueur Wine	(-23.76)±0.2	12.76±0.3	(-219.09)±1.09
5	Liqueur Wine	(-24.33)±0.21	13.04±0.28	(-247.87)±1.12
6	Liqueur Wine	(-18.09)±0.18	9.54±0.3	(-249.09)±1.1
7	Liqueur Wine	(-20.87)±0.21	8.43±0.28	(-230.21)±1.12
8	Liqueur Wine	(-11.87)±0.19	10.12±0.3	(-238.75)±1.1
9	Liqueur Wine	(-28.32)±0.2	0.31±0.3	(-180.21)±1.1

The isotope characteristics of ethanol carbon of sample No. 4 indicate the presence of alcohols of non-trivial origin. obtained from C-4 plants of the type of photosynthesis (corn. sugar cane). The values of д^{18}O and дD are included in the range established for grape alcohols.

The value of the indicator д^{13}C for ethanol extracted from sample No. 5 equal to minus 24.33 can indicate the presence of alcohols derived from C-4 plants of the type of photosynthesis (corn. sugar cane) or about obtaining this sample from grain alcohols. The ratio of oxygen and hydrogen isotopes (д^{18}O-13.04 ‰. дD-minus 247.87). characteristic for grain alcohols. also speak of this.

Samples No. 6 and No. 7 are blended products made from biogenic alcohols of various origins. The values of д^{13}C and д^{18}O obtained for ethanol. extracted from these wines indicate the presence of alcohols. obtained from carbohydrates of C-4 plants of the type of photosynthesis. At the same time. the values of дD. equal to minus 249.09 ‰ and minus 230.21 ‰. may indicate the presence of grain alcohols.

The isotope characteristics of light elements of ethanol. extracted from sample No. 8 allow us to evaluate this sample as a counterfeit. completely prepared from sugars/alcohols made from sugar cane.

As for sample No. 9. having values of д^{13}C minus 28.32 ‰. д^{18}O. equal to 0.31 ‰ and дD minus 180.21 ‰. the fact of adding abiogenic alcohol to the product is clearly revealed here. The value of д^{18}O. close to zero. and the displacement of the isotope characteristics of hydrogen toward the increase in the share of "heavy" deuterium. unequivocally indicate the presence of alcohols of abiogenic origin.

Based on the results of the studies. the following conclusions can be drawn:

- when wine and liqueur wines are added to biogenic alcohols of an innocent origin. the isotope characteristics of the light elements of ethanol change in the direction of increasing or decreasing the proportion of "heavy" isotopes depending on the type of raw material from which the exogenous alcohol was produced;

- when abiogenic alcohols are added to wine. the oxygen and hydrogen isotopes are deeply fractionated. the value of д^{18}O goes to the negative numerical range or is close to zero. which indicates a significant increase in the fraction of the "light" isotope ^{18}O. At the same time. the proportion of deuterium increases. as evidenced by the high values of the дD. Isotope characteristics of carbon can be included in the numerical range. characteristic for alcohols of grape origin.

Thus. by measuring the isotope characteristics of the three elements of the alcohol molecule - carbon. oxygen and hydrogen. the presence of alcohols of abiogenic origin can be detected with a high degree of certainty in wines.

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ЖҮЗІМ ШАРАПТАРЫНДАҒЫ АБИОГЕНДІ СПИРТТЕРДІ АНЫҚТАУҒА ИЗОТОПТЫ МАСС-СПЕКТРОМЕТРИЯНЫ ҚОЛДАНУ

Аннотация. Тәжірибе көрсеткендей, тұрақты көмірсу изотоптарының ^{13}C/^{12}C сипаттайтын бір көрсеткіш d13C ‰, әсіресе, абиогендік спирттер өнімге қосылса, жүзім емес заттардан спирттерді анықтау үшін жеткіліксіз.

Этанол молекуласының элементтерінің изотоптарын сипаттайтын аспаптық база ^{13}C/^{12}C, ^{18}O/^{16}O, D/H изотоптарының таралу коэффициенттерін нақты талдауды қамтамасыз ететін Thermo Fisher Scientific (АҚШ) компаниясының Delta V Advantage масс-спектрометрия кешені болды. Этилен гидратациясымен алынған абиогендік спирттегі оттегінің изотоптық сипаттамалары осы көрсеткіштен өсімдік текті заттардың барлық спирттерінен айтарлықтай ерекшеленетіндігі анықталды. Көптеген өсімдіктерден алынған спирттерінің оттегінің изотоптық сипаттамалары д^{18}O‰-ден 5,38‰ ден 16,29‰-ға дейін түседі, тек қана қызылша спирті үшін сандық мәндер шамалы төмен, атап айтқанда: 1,66–2,05‰. Сонымен бірге, абиогенді этанол үшін д^{18}O‰ мәнінің мәні теріс және минус 14.21 ‰ – минус 15,20‰. болып табылады. Бұл елеулі айырмашылықтар осы көрсеткішті пайдаланып, қолданылатын спирттердің – өсімдік текті немесе абиогендік туралы айтуға мүмкіндік береді. дD‰ көрсеткішін талдай отырып, абиогендік спирттің сутегі өсімдік алкоголі бар сутегіне қарағанда айтарлықтай «ауыр» екенін және қарама қарсы минус 213‰ – минус 266 ‰ минус 140‰ – минус 153‰ екенін атап өтуге болады. Алынған мәндерді пайдалана отырып, асханалық шараптың 24 үлгісі зерттелді. Бұл жағдайда екі үлгіде д^{13}C минус 28,22 ‰ және минус 28,41‰ мәндері бар, д^{18}O минус 1,0‰

және минус 0,76‰, бұл өнімдегі абиогендік спирт бар екендігін білдіреді. Өсімдік шикізатынан алынған спирттерге тән «ауыр» сутегі dD (минус 172.66 ‰) және dD (минус 169.43) жасалған қорытындыларды ғана растайды. Осындай зерттеулер ликер шараптары үшін өткізілді. Осылайша, спирт молекулаларының үш элементтің – көміртек, оттек және сутегінің изотоптық сипаттамаларын өлшеу арқылы, шараптың құрамында абиогендік спирттердің бар екендігі туралы жоғары сенімділікпен анықтауға болады.

Түйін сөздер: шарап, сусындарды сәйкестендіру, изотоптық масс-спектрометрия, шарап этанолы, абиогенді спирттер, этанол молекулаларының элементтерінің изотоптық қатынасы.

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ПРИМЕНЕНИЕ ИЗОТОПНОЙ МАСС-СПЕКТРОМЕТРИИ ДЛЯ ВЫЯВЛЕНИЯ АБИОГЕННЫХ СПИРТОВ В ВИНОГРАДНЫХ ВИНАХ

Аннотация. Практика показывает, что одного показателя д^{13}C‰, характеризующего отношение стабильных изотопов углерода $^{13}C/^{12}C$, в ряде случаев недостаточно для обнаружения в винах спиртов невиноградного происхождения, особенно когда в продукт внесены абиогенные спирты. Инструментальной базой, обеспечивающей получение характеристик изотопов элементов молекул этанола, служил масс-спектрометрический комплекс Delta V Advantage фирмы Thermo Fisher Scientific (США), обеспечивающий прецизионный анализ отношений распространенности $^{13}C/^{12}C$, $^{18}O/^{16}O$, D/H изотопов. Установлено, что изотопные характеристики кислорода абиогенного спирта, полученного гидратацией этилена, значительно отличаются от данного показателя для всех спиртов растительного происхождения. Изотопные характеристики кислорода большинства растительных спиртов укладываются в диапазон д^{18}O‰ от 5,38 до 16,29‰, и только для свекловичного спирта числовые значения несколько ниже, а именно: 1,66–2,05‰. В то же время значение показателя д^{18}O‰ у абиогенного этанола имеет отрицательный знак и составляет минус 14,21‰ – минус 15,20‰. Эти существенные отличия позволяют использовать данный показатель для установления природы используемых спиртов – растительного или абиогенного происхождения. Анализируя показатель дD‰, можно отметить, что водород абиогенного спирта заметно «тяжелее» водорода, содержащегося в спиртах растительного происхождения и составляет минус 140‰ – минус 153‰ против минус 213‰ – минус 266‰. Используя полученные величины, исследовали 24 образца столовых вин. При этом два образца имели значение д^{13}C минус 28,22‰ и минус 28,41‰ соответственно, д^{18}O минус 1,0‰ и минус 0,76‰, что указывает на наличие в продукте абиогенного спирта. «Тяжелый» водород дD (минус 172,66‰) и дD (минус 169,43‰), не характерный для спиртов из растительного сырья, только подтверждают сделанный вывод. Аналогичные исследования проведены для ликерных вин. Таким образом, измеряя изотопные характеристики трех элементов молекул спирта – углерода, кислорода и водорода, можно с высокой степень достоверности обнаруживать в винах присутствие спиртов абиогенного происхождения.

Ключевые слова: вино, идентификация напитков, изотопная масс-спектрометрия, винный этанол, абио-генные спирты, отношение изотопов элементов молекул этанола.

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REFERENCES

[1] Churshudyan S.A. (**2014**). Consumer and Food Quality // Food Industry. 5:16-18 (in Rus.).

[2] Petrov A.N. and other. (**2017**). Indicators of Canned Milk Quality: Russian and International Priorities // Foods and Raw Materials. 5:2:151-161 (in Eng.).

[3] Petrov A.N., Khanferyan R.A., Galstyan A.G. (**2016**). Actual Aspects of Counteraction of Food Falsification // Nutrition Issues. 5:86-92 (in Rus.).

[4] Guyon F., Douet C., Colas S., Salagoity M.H., Medina B. (**2006**). Effect of Must concentration Techniques on Wine Isotopic Parameters // J. Agricul. Food Chem. 54: 9918-9923. doi10.1021/jf062095f (in Eng.).

[5] Dutra S.V., Adami L., Marcon A.R., et.al. (**2013**). Characterization of wines according the geographical origin by analysis of isotopes and minerals and the influence of harvest on isotope values // Food Chem. 141:2148-2153. doi: 10.1007/s00216-011-5269-8} (in Eng.).

[6] Adami L., Dutra S.V., Marcon A.R., et al. (**2010**). Geographic origin of southern Brazilian wines by carbon and oxygen isotope analysis // Rapid Commun. Mass Spectrometry. 24: 2943-2948. doi: 10.1002/rcm.4726 (in Eng.).

[7] Galimov E.M. (**1981**). Nature of biological isotope fractionation. Science. P. 220 (in Rus.).

[8] Zyakun A.M. (**2010**). Theoretical Foundations of Isotope Mass Spectrometry in Biology. Photon-age. P. 247 (in Rus.).

[9] Oganesyants L.A., Panasyuk A.L., Kuzmina E.I., Zyakun A.M. (**2015**). Isotopic features of ethanol of the russian grape wine // Winemaking and Viticulture. 4:8-13 (in Rus.).

[10] Thomas F., Jamin E. (**2009**). ^{2}H NMR and ^{13}C-IRMS analyses of acetic acid from vinegar, ^{18}O-IRMS analysis of water in vinegar: International collaborative study report // Analytica Chimica Acta. 649:1:98-105. doi: 10.1016/j.aca.2009.07.014 (in Eng.).

[11] Gilbert A., Hattori R., Silvestre V., et. al. (**2012**). Comparison of IRMS and NMR spectrometry for the determination of intramolecular ^{13}C isotope composition: Application to ethanol // Talanta. 99:1035-1039. doi: 10.1016/j.talanta.2012.05.023 (in Eng.).

[12] Guyon F., Auberger P., Gaillard L., Loublanches C., Viateau M., Sabathii N., Salagoпty M., Midina B. (**2014**). ^{13}C/^{12}C isotope ratios of organic acids, glucose and fructose determined by HPLC-co-IRMS for lemon juices authenticity // Food Chemistry. 146:36-40. doi: 10.1016/j.foodchem.2013.09.020 (in Eng.).

[13] Camin F., Bontempo L., Perini M., Tonon A., Breas O., Guillou C., Moreno-Rojas J.M., Gagliano G. (**2013**). Control of wine vinegar authenticity through д^{18}O analysis // Food Control. 29:1:107-111. doi: 10.1016/j.foodcont.2012.05.055 (in Eng.).

[14] Fan S., Zhong Q., Gao H., Wang D., Li G., Huang Z. (**2018**). Elemental profile and oxygen isotope ratio (д^{18}O) for verifying the geographical origin of Chinese wines" // Journal of Food and Drug Analysis. 26:3:1033-1044. doi: 10.1016/j.jfda.2017.12.009} (in Eng.).

[15] Kiran K.P., Ramesh R., Singh A. (**2018**). Controls on д18O, дD and д^{18}O-salinity relationship in the northern Indian Ocean // Marine Chemistry. 207:55-62 (in Eng.).

[16] Raidla V., Kern Z., Рдrn J., Babre A., Vaikmде R. (**2016**). A д^{18}O isoscape for the shallow groundwater in the Baltic Artesian Basin // Journal of Hydrology. 542:254-267. doi: 10.1016/j.jhydrol.2016.09.004 (in Eng.).

[17] Chaintreau A., Fieber W., Sommer H., Gilbert A., Yamada K., Yoshida N., Pagelot A., Moskau D., Moreno A., Schleucher J., Reniero F., Holland M., Guillou C., Silvestre V., Akoka S., Remaud G.S. (**2013**). Site-specific ^{13}C content by quantitative isotopic ^{13}C nuclear magnetic resonance spectrometry: a pilot inter-laboratory study // Anal Chim Acta.788:108-13. doi: 10.1016/j.aca.2013.06.004 (in Eng.).

[18] Hajati M., Frandsen M., Pedersen O., Nilsson B., Engesgaard P. (**2018**). Flow reversals in groundwater–lake interactions: A natural tracer study using д^{18}O // Limnologica. 68: 26-35. doi: 10.1016/j.limno.2017.04.006 (in Eng.).

[19] Green D.R., Olack G., Colman A.S. (**2018**). Determinants of blood water д^{18}O variation in a population of experimental sheep: Implications for paleoclimate reconstruction // Chemical Geology. 485:32-43. doi: 10.1016/j.chemgeo.2018.03.034 (in Eng.).

[20] Insel N., Poulsen C.J., Ehlers T.A., Sturm C. (**2012**). Response of meteoric д^{18}O to surface uplift - Implications for Cenozoic Andean Plateau growth // Earth and Planetary Science Letters. 317:318:262-272. doi: 10.1016/j.epsl.2011.11.039 (in Eng.).

[21] Ooki S., Akagi T., Jinno H., Franzйn L.G., Newton J. (**2018**). Hydrological study of Lyngmossen bog, Sweden: Isotopic tracers (^{3}H, д^{2}H and д^{18}O) imply three waters with different mobilities // Quaternary Science Reviews. 199:97-107. doi: 10.1016/j.quascirev.2018.09.014 (in Eng.).

[22] Nakata K., Hasegawa T., Oyama T., Miyakawa K. (**2018**). Evaluation of д^{2}H and д^{18}O of water in pores extracted by compression method-effects of closed pores and comparison to direct vapor equilibration and laser spectrometry method // Journal of Hydrology. 561:547-556. doi: 10.1016/j.jhydrol.2018.03.058 (in Eng.).

[23] Oganesyants L.A., Panasyuk A.L., Kuzmina E.I. (**2016**). Analysis of isotopic characteristics of wine products water component oxygen // Winema-king and Viticulture. 6:4-6 (in Rus.).

[24] Oganesyants L.A., Khurshudyan S.A., Galstyan A.G., Semipyatny V.K., Ryabova A.E., Vafin R.R., Nurmukhanbetova D.E., Assembayeva E.K. (**2018).** Base matrices – invariant digital identifiers of food products // News «Series of Geology and Technical Sciences». N 6. P. 6-15. ISSN 2224-5278d. https://doi.org/10.32014/2018.2518-170X.30

[25] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[26] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[27] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

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APPROBATION OF PCR-RFLP AND AS-PCR METHODS FOR GENOTYPING CATTLE BY THE DGAT1 GENE

Abstract. The DGAT1 gene Bos taurus is an economically valuable lipid metabolism gene in cattle, affecting upon milk production and milk quality, the allele polymorphism assessment of which is diagnostically significant. The purpose of this work was to test a number of methods for carrying out PCR-RFLP and AS-PCR for genotyping cattle using allelic variants of the DGAT1 gene and then evaluating allelic polymorphism in the studied animal sample in the context of consistency of the used molecular genetic approaches. Studies have been conducted on a sample of mixed and pure bred Holstein cattle. DNA Extraction from samples of whole canned blood of cattle carried out by the combined alkaline method. Proven methods of genotyping effectively identified the analyzed genotypes, showing consistent with each other reliable results, in accordance with the calculated data of alignments analysis, restriction mapping and simulations of generated PCR and RFLP profiles.

Keywords: Bos taurus, DGAT1, allele: genotype, genotyping, PCR, RFLP.

Introduction. PCR-RFLP (Polymerase Chain Reaction – Restriction Fragment Length Polymorphism) – combined molecular genetic method for genotyping animals [1], plants [2], bacteria [3] and viruses [4], where the length of the generated amplicons and restricts is analyzed for single nucleotide polymorphism (SNP) and allelic polymorphism in eukaryotes, in particular, with the subsequent conclusion about the homozygous or heterozygous state of a certain gene of the individual being studied.

Various modifications of PCR-RFLP analysis [5-7] have found practical application in evaluating the allelic polymorphism of *DGAT1* (diacylglycerol o-acyltransferase 1) *Bos taurus*, an economic-valuable lipid metabolism gene in cattle [8, 9], affecting on milk production and milk quality in the context of the content and yield of milk fat [10-12], as well as fat-acid, protein and mineral composition of milk [9], which is especially important in the production of functional and gerodietic dairy products [13-15, 21].

Along with this, other of SNP detection methods, such as AS-PCR (Allele-Specific PCR) [16], direct sequencing of the amplified gene locus, HRM analysis (High Resolution Melting) [17] and Real-time PCR [16, 18].

The goal of the study was to test a number of PCR-RFLP and AS-PCR methods for genotyping cattle using allelic variants of the *DGAT1* gene and then evaluating allelic polymorphism in the studied animal sample in the context of consistency of the molecular used genetic approaches.

Materials and Methods. Studies were conducted on a sample of mixed and pure bred Holstein cattle of one of the breeding enterprises of the Russian Federation.

Extraction of nucleic acid from samples of whole blood of cattle, canned 10 mm EDTA-Na2, carried out by the combined alkaline method [19].

Tested methods of PCR-RFLP and AS-PCR for cattle genotyping for alleles *A* and *K* of the *DGAT1* gene were performed on a "Tertsik" amplifier ("DNA -Technology, Russia) in volumes of 20 μl,

containing standard buffer (60 mM Tris -HCl (pH 8.5); 1.5 mM MgCl2; 25 mM KCl; 10 mM 2-mercaptoethanol; 0.1% Triton X-100), 0.25 mM dNTP, 1 U Taq DNA polymerase, 0.25 mM of direct standard (DGAT1-F [19]) and allele-specific primers (DGAT1-1 + DGAT1-2 [7] and DGAT1A + + DGAT1K [16]), 0.5 μM of reverse common primers (DGAT1-R [19], DGAT1-3 [7] and DGAT1R [16]), 1 μl of the DNA sample in the following thermal cycling modes:

PCR with primers DGAT1-F + DGAT1-R:

×1: 94°C – 4 min; ×35: 94°C – 60 sec., 59°C – 30 sec., 72°C –30 sec.; ×1: 72°C – 10 min; storage: 4°C.

PCR with primers DGAT1-1 + DGAT1-2 + DGAT1-3:

×1: 94°C – 4 min; ×40: 94°C – 10 sec., 72°C – 10 sec.; ×1: 72°C – 5 min; storage: 4°C.

PCR with primers DGAT1A + DGAT1K + DGAT1R:

×1: 94°C – 4 min; ×40: 94°C – 20 sec., 65°C – 20 sec., 72°C – 20 sec; ×1: 72°C – 5 min; storage: 4°C.

The sequence of used oligonucleotide primers sets is presented in table 1.

Table 1 – Oligonucleotide Primers Sets for PCR-RFLP and AS-PCR

Oligonucleotide Primers Sets for PCR-RFLP and AS-PCR	Ref
DGAT1-F: 5/-GCACCATCCTCTTCCTCAAG-3/ DGAT1-R: 5/-GGAAGCGCTTTCGGATG-3/	[19]
DGAT1-1: 5/-CCGCTTGCTCGTAGCTTTCGAAGGTAACGC-3/ DGAT1-2: 5/-CCGCTTGCTCGTAGCTTTGGCAGGTAACAA-3/ DGAT1-3: 5/-AGGATCCTCACCGCGGTAGGTCAGG-3/	[7]
DGAT1A: 5/-CGTAGCTTTGGCAGGTAAAGC-3/ DGAT1K: 5/-CCGCTTGCTACTAGCTTTGGCAGGTAACAA-3/ DGAT1R: 5/-TCAGGTTGTCGGGGTAGCTC-3/	[16]

To determine the allelic polymorphism of the *DGAT1* gene with use of allelic variants *A* and *K*, 20 μl of PCR samples were treated with 10 U of *Aco*I restrictase in 1× buffer “G” at 37 °C (DGAT1-F + +DGAT1-R) and 20 U of *Taq*I restrictase in 1 × buffer "Y" (DGAT1-1 + DGAT1-2 + DGAT1-3) at 65 °C overnight.

The results of PCR-RFLP and AS-PCR were detected by horizontal electrophoresis in 3% agarose gel in TBE buffer (pH 8.0), containing ethidium bromide at a concentration of 0.5 μg/ml, followed by visualization of the amplified products in an ultraviolet transilluminator (λ = 310 nm).

We used reagents for molecular biological studies produced by SibEnzyme LLC (Russia) and DNA-Synthesis LLC (Russia).

$$p = n/N,$$

where p - genotypes frequency; n - number of animals having a certain genotype; N - total number of examined animal units.

The calculation of individual alleles frequency is determined by the formula:

$$p = (2N1+N2)/2n,$$

where $N1$ - homozygotes number for studied allele; $N2$ - heterozygotes number; n - sample size.

To compare the observed and expected frequency distribution of genotypes, the chi-square correspondence criterion is used (χ^2).

The expected genotypes frequencies in the studied sample are calculated according to the Hardy-Weinberg law.

The obtained results were processed by a biometric method using computer and Microsoft Excel software application. The level of their reliability is determined by the Student criterion.

Results and discussion. Calculated data for verification of PCR-RFLP and AS-PCR validated methods were obtained based on alignment analysis, *Aco*I and *Taq*I restriction mapping of amplified partial nucleotide sequences of *A* and *K* allelic variants DGAT1 *Bos taurus* gene with modeling of the generated PCR and RFLP profiles of the corresponding genotypes .

Thus, the well-known primers DGAT1-F and DGAT1-F [19] initiate amplification of the cattle DGAT1 gene locus with a length of 411 bp, and AcoI-RFLP analysis of the genotype-specific fragments generated (*AA* = 208/203 bp, *KK* = 411 bp and *AK* = 411/208/203 bp) provides the correct genotyping procedure (table 2).

Table 2 – Oligonucleotide Primers First Set for PCR-RFLP

Oligonucleotide Primers Set	PCR Product (bp)	*Aco*I-RFLP Fragments		
		DGATI genotypes		
		AA	*KK*	*AK*
DGAT1-F + DGAT1-F	411	208 203	411	411 208 203

Another tested primer set DGAT1-1 + DGAT1-2 + DGAT1-3 [7] triggers the amplification of DGAT1 *Bos taurus* gene locus with a length of 100 bp followed by the generation of DGAT1-PDLP-*Taq*I profiles (*AA* = 82/18 bp, *KK* = 100 bp and *AK* = 100/82/18 bp) (table 3).

Table 3 – Oligonucleotide Primers Second Set for PCR-RFLP

Oligonucleotide Primers Set	PCR Product (bp)	*Taq*I-RFLP Fragments		
		DGATI genotypes		
		AA	*KK*	*AK*
DGAT1-1 + DGAT1-2 + DGAT1-3	411	82 18	100	100 82 18

The result of modeling the generated PCR and *Taq*I-RFLP profiles of the corresponding genotypes for the *DGAT1* gene is presented in figure 1.

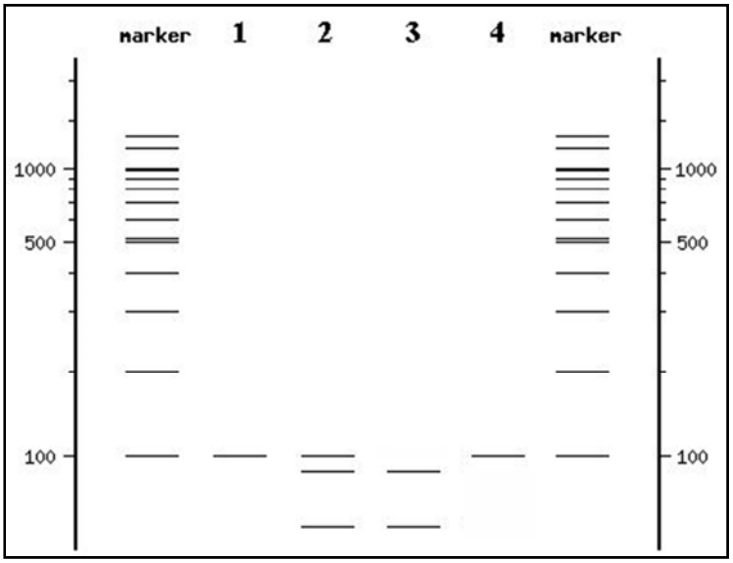

Figure 1 – DGAT1-PCR-RFLP-TaqI Profile of Bos taurus with Primers DGAT1-1 + DGAT1-2 + DGAT1-3.

Note: 1) PCR-product (100 bp); 2-4) RFLP-fragments: 2) genotype *AK* (100/82/18 bp); 3) genotype *AA* (82/18 bp); 4) genotype *KK* (100 bp).

An illustrative result of PCR-RFLP for genotyping cattle by alleles *A* and *K* of the *DGAT1* gene with the corresponding primers (DGAT1-1 + DGAT1-2 + DGAT1-3) and endonuclease digestion with the restriction enzyme *Taq*I is presented in figure 2

At the same time, a distinctive feature of this approach is that at the PCR stage, the “Single PCR” formulation uses three primers, one of which (DGAT1-3) is common for both alleles of the analyzed gene, and the other two (DGAT1-1 + DGAT1- 2) - allele-specific, but with a given restriction identification site for one of them (DGAT1-1), and artificially created, but not affecting the analyzed SNP itself, which is a competitive advantage when choosing the desired restriction enzyme (figure 3).

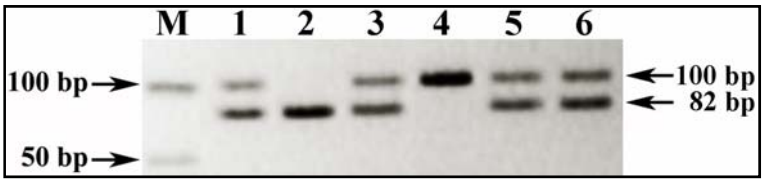

Fig. 2 Electrophoregram of the Result of a PCR-RFLP with the Primers DGAT1-1 + DGAT1-2 + DGAT1-3 and endonuclease digestion with the restriction enzyme TaqI for genotyping Bos taurus on the Allelic Variants A and K of the DGAT1 gene.

Note: M) DNA Molecular Weight Marker (100 bp + 50 bp ladder); 1, 3, 5, 6) genotype *AK* (100/82/18 bp); 2) genotype *AA* (82/18 bp); 4) genotype *KK* (100 bp).

```
                                  TaqI
                CCGCTTGCTC GTAGCTTTCG AAGGTAACGC = A-allele specific primer
DGAT1-gene      CCGCTTGCTC GTAGCTTTGG CAGGTAACAA = K-allele specific primer
Allele A   001 CCGCTTGCTC GTAGCTTTGG CAGGTAAGGC GGCCAACGGG GGAGCTGCCC
Allele K   001 .......... .......... ........AA .......... ..........

                                                          Common primer PCR
DGAT1-gene                                      CCTGA CCTACCGCGG TGAGGATCCT product
Allele A   051 AGCGCACCGT GAGCTACCCC GACAACCTGA CCTACCGCGG TGAGGATCCT 100 bp
Allele K   051 .......... .......... .......... .......... .......... 100 bp

DGAT1-gene Taq1-restriction mapping Taq1-PCR-RFLP-profile
Allele A   1-18/19-100              82/18 bp
Allele K   100                     100 bp
```

Figure 3 – Aligning and Taq-Restriction Mapping of the Nucleotide Sequence of DGAT1-gene locus of the Bos taurus Flanked with Primers DGAT1-1 + DGAT1-2 + DGAT1-3 (Alleles A and K)

The third tested primer set DGAT1A + DGAT1K + DGAT1R [16] also provides effective identification of the desired genotypes (*AA, KK, AK*) due to the correct interpretation of the generated 80-bp and/or 71 bp genotypes (table 4).

Table 4 – Oligonucleotide Primers Third Set for AS-PCR

Oligonucleotide Primers Set	PCR Product		
	DGATI genotypes		
	AA	*KK*	*AK*
DGAT1A + DGAT1K + DGAT1R	71	80	80 71

An illustrative electrophoretic picture of the AS-PCR result for the genotyping of cattle by alleles *A* and *K* of the *DGAT1* gene with a set of oligonucleotide primers DGAT1A + DGAT1K + DGAT1R is shown in figure 4.

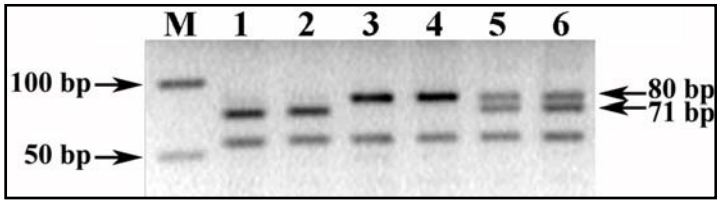

Figure 4 – Electrophoregram of the Result of a AS-PCR with the Primers DGAT1A + DGAT1K + DGAT1R for Genotyping Bos taurus on the Allelic Variants A and K of the DGAT1 gene.

Note: M) DNA Molecular Weight Marker (100 bp + 50 bp ladder); 1-2) genotype *AA* (71 bp); 3-4) genotype *KK* (80 bp); 5-6) genotype *AK* (80/71 bp).

This method of carrying out PCR for genotyping cattle in allelic variants A and K of the DGAT1 gene with detection in agarose gel electrophoresis is a type of allele-specific PCR (AS-PCR) [20].

It effectively discriminates against single nucleotide substitutions (SNPs) in the "Single PCR" formulation when using two forward allele-specific primers of different lengths with 3/- end bases complementary to the SNP site (DGAT1A + DGAT1K and one common reverse primer (DGAT1R), together initiating amplification of allele-specific PCR products of various lengths, separated in agarose gel electrophoresis (figure 5).

```
                          CGTAGCTTTGGCAGGTAAAGC = A-allele-specific primer
DGAT1-gene          CCGCTTGCTACTAGCTTTGGCAGGTAACAA = K-allele-specific primer
Allele A   01               CGTAGCTTTGGCAGGTAAGGCGGCCAACGGGGGAGCTGCCCAGC
Allele K   01 CCGCTTGCT...................AA.......................

                              Common primer PCR-
DGAT1-gene                 GAGCTACCCCGACAACCTGA product
Allele A   45 GCACCGTGAGCTACCCCGACAACCTGA 71 bp
Allele K   54 ............................ 80 bp
```

Figure 5 – Aligning of the Nucleotide Sequence of DGAT1 gene locus of the Bos taurus Flanked with Primers DGAT1A + DGAT1K + DGAT1R (Alleles A and K)

At the same time, to increase the specificity of the reaction, an unpaired nucleotide in the 3rd position from the 3/- end of oligonucleotides is introduced into the allele-specific primers, as well as two additional mismatch nucleotides in the 20th and 21st positions only in the DGATK primer.

The approved genotyping methods showed identical results of the evaluation of the allelic polymorphism of the *DGAT1* gene in the sample of manufacturing bulls, whose data are presented in table 5.

Table 5 –Allelic polymorphism of the DGAT1 gene in the studied sample of servicing bulls

N=70	Occurrence Frequency								$\chi 2$
	genotypes						*alleles*		
	AA		*AK*		*KK*		*A*	*K*	
	n	*%*	*n*	*%*	*n*	*%*			
O	38	54.3	28	40.0	4	5.7	0.74	0.26	0.24
E	38	54.3	27	38.6	5	7.1			
Note: O – actually observed indicator, E – theoretically expected indicator.									

So, bulls, which are mixed and pure bred Holstein cattle, the frequency of allele *A* was 0.74, allele *B* - 0.26, and genotype distribution was as follows: *AA* - 38 heads (54.3%), *AK* - 28 heads (40.0%), *KK* - 4 heads (5.7%).

The observed frequency distribution of genotypes in the studied sample corresponds to the theoretically expected Hardy-Weinberg equilibrium distribution.

Conclusion. PCR-RFLP and AS-PCR methods for genotyping cattle using allelic variants *A* and *K* of the *DGAT1* gene effectively identified the analyzed genotypes, showing reliable results consistent with each other, in accordance with the calculated data of alignment analysis, restriction mappings and modeling of the generated profiles, comparable with the results of a previous study on the same sample of manufacturing bulls [7].

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DGAT1 ГЕНІ БОЙЫНША ІРІ ҚАРА ЖАНУАРЛАРЫН ГЕНОТИПТЕНДІРУ ҮШІН PCR-RFLP ЖӘНЕ AS-PCR ӘДІСТЕРІН СЫНАҚТАН ӨТКІЗУ

Аннотация. *DGAT1 Bos taurus* – бұл малдың сүттілігіне және сапасына әсер ететін, аллельдік полиморфизмді бағалауда диагностикалық мәні бар ірі қара жануарының май алмасуына қатысатын маңызды ген. Осы жұмыстың мақсаты – DGAT1 генінің аллельді нұсқаларын қолдану арқылы PCR-RFLP және AS-PCR операцияларын жүргізудің бірқатар әдістерін сынақтан өткізу, содан кейін зерттелген жануарлар үлгісінде қолданылатын молекулалық генетикалық тәсілдердің үйлесімділігі тұрғысында аллельді полиморфизмді бағалау. Зерттеулер жергілікті және таза тұқым голштин ірі қара малы бойынша жүргізілді. Біріктірілген сілтілі әдіспен жүргізілген малдың толық консервіленген қанының үлгілерінен ДНҚ алынды. Генотиптіліктің дәлелденген әдістері есептелген деректерді талдауға сәйкес, PCR және RFLP профилдерімен генерациялайтын шектеуді картаға түсіру және модельдеуге сәйкес, бір-біріне сенімді нәтижелерге сәйкес келетін талданатын генотиптер тиімді түрде анықталды.

Түйін сөздер: Bos taurus, DGAT1, аллель: генотип, генотиптеу, ТР, RFLP.

А. Е. Рябова[1], И. Ю. Михайлова[1], Х. Х. Гильманов[1], И. В. Ржанова[1], Э. К. Асембаева[2], Д. Е. Нурмуханбетова[2]

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АПРОБАЦИЯ СПОСОБОВ ПРОВЕДЕНИЯ PCR-RFLP И AS-PCR ДЛЯ ГЕНОТИПИРОВАНИЯ КРУПНОГО РОГАТОГО СКОТА ПО ГЕНУ DGAT1

Аннотация. Ген *DGAT1 Bos taurus* – хозяйственно-ценный ген липидного обмена у крупного рогатого скота, влияющий на молочную продуктивность и качество молока, оценка аллельного полиморфизма которого диагностически значима. Целью настоящей работы являлась апробация ряда способов проведения PCR-RFLP и AS-PCR для генотипирования крупного рогатого скота по аллельным вариантам гена *DGAT1* с последующей оценкой аллельного полиморфизма у исследуемой выборки животных в контексте согласованности использованных молекулярно-генетических подходов. Исследования проведены на выборке помесного и чистопородного голштинского скота. Экстракция ДНК из образцов цельной консервированной крови крупного рогатого скота осуществлена комбинированным щелочным способом. Апробированные способы генотипирования эффективно идентифицировали анализируемые генотипы, показав согласованные друг с другом достоверные результаты, в соответствии с расчетными данными анализа выравниваний, рестрикционных картирований и моделирований генерируемых PCR и RFLP профилей.

Ключевые слова: Bos taurus, DGAT1, аллель: генотип, генотипиование, ПЦР, RFLP.

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REFERENCES

[1] Tyulkin S.V., Akhmetov T.M., Valiullina E.F. and Vafin R.R. (**2013**). Polymorphism of Somatotropin, Prolactin, Leptin, and Thyreoglobulin Genes in Bulls // Russian Journal of Genetics: Applied Research. 3(3): 222-224. doi: 10.1134/S2079059713030118

[2] Vafin R.R., Rzhanova I.V., Askhadullin D-l.F., Askhadullin D-r.F. etc. (**2015**). Identification of Triticum aestivum L. genotype by Allelic Versions of Waxy-Genes and HMW Glutenin Subunits // Ecology, Environment and Conservation Paper. 21(Nov. Suppl. Issue): 137-143.

[3] Vafin R.R., Ravilov R.Kh., Gaffarov Kh.Z., Ravilov A.Z. etc. (**2007**). A Contribution to the Nomenclature and Classification of Chlamydiae // Mol. Gen. Mikrobiol. Virusol. 4: 17-25 (in Rus.).

[4] Vafin R.R., Khazipov N.Z., Shaeva A.Y., Zakirova Z.R., etc. (**2014**). Genotypic Identification of the Bovine Leukemia Virus // Mol. Genet. Microbiol. Virol. 29(4): 195-203. doi: 0.3103/S0891416814040120

[5] Komisarek J., Michalak A. (**2008**). A Relationship Between DGAT1 K232A Polymporphism and Selected Reproductive Traits in Polish Holstein-Friesian Cattle // Anim. Sci. Pap. Rep. 26(2): 89-95.

[6] Ahani S., Mashhadi M.H., Nassiri M.R., Aminafshar M. etc. (**2015**). Characterization of Single Nucleotide Polymorphism in Diacylglycerol Acyltransferase (DGAT1) gene loci of Iranian Holstein Cattle // Research Opinions in Animal and Veterinary Sciences. 5(5): 231-236.

[7] Tyulkin S.V., Vafin R.R., Muratova A.V., Khatypov I.I. etc. (**2015**). Development of a Method for PCR-RFLP on the Example of DGAT1 gene in Cattle // Fundamental Research. 2: 3773-3775 (in Rus.).

[8] Berry D.P., Howard D., O'Boyle P., Waters S., etc (**2010**). Associations Between the K232A Polymorphism in the Diacylglycerol-O-Transferase 1 (DGAT1) gene and Performance in Irish Holstein-Friesian Dairy Cattle // Ir. J. Agric. Food Res. 49(1): 1-9.

[9] Bovenhuis H., Visker M.H.P.W., Poulsen N.A., Sehested J., etc. (**2016**). Effects of the Diacylglycerol O-acyltransferase 1 (DGAT1) K232A Polymorphism on Fatty Acid, Protein, and Mineral Composition of Dairy Cattle Milk // J. Dairy Sci. 99(4): 1-11. doi: 10.3168/jds.2015-1046

[10] Cardoso S.R., Queiroz L.B., Goulart V.A., Mourão G.B., etc. (**2011**). Productive Performance of the Dairy Cattle Girolando Breed Mediated by the Fat-Related genes DGAT1 and LEP and their Polymorphisms // Res. Vet. Sci. 91(3): 107-112. doi: 10.1016/j.rvsc.2011.02.006

[11] Komisarek J., Michalak A., Walendowska A. (**2011**). The Effects of Polymorphisms in DGAT1, GH and GHR genes on Reproduction and Production Traits in Jersey Cows // Anim. Sci. Pap. Rep. 29(1): 29-36.

[12] Molee, Duanghaklang N. and Na-Lampang P. (**2012**). Effects of Acyl-CoA:diacylglycerol Acyl Transferase 1 (DGAT1) gene on Milk Production Traits in Crossbred Holstein Dairy Cattle // Trop. Anim. Health Prod. 44(4): 751-755. doi: 10.1007/s11250-011-9959-1

[13] Petrov A.N., Galstyan A.G., Radaeva I.A., Turovskaya S.N. etc. (**2017**). Indicators of Canned Milk Quality: Russian and International Priorities // Foods and Raw Materials. 5(2): 151-161. doi: 10.21179/2308-4057-2017-2-151-161

[14] Galstyan A.G., Petrov A.N., Radaeva I.A., Sarukhanyan O.O., etc. (**2016**). Scientific Bases and Technological Principles of Gerodietetic Canned Milk Production // Voprosy pitaniia. 85(5): 114-119 (in Rus.).

[15] Asembaeva E.K., Galstyan A.G., Khurshudyan S.A., Nurmukhanbetova D.E., etc. (**2017**). Development of Technology and Study of the Immunobiological Properties of a Sour Milk Beverage Based on Camel Milk // Voprosy pitaniia. 86(6): 67-73 (in Rus.).

[16] Vafin R.R., Tyulkin S.V., Zagidullin L.R., Muratova A.V., etc. (**2016**). Development of PCR Methods for Cattle Geno-typing by Allelic Variants of DGAT1 Gene // Research Journal of Pharmaceutical, Biological and Chemical Sciences. 7(2): 2075-2080.

[17] Abdolmohammadi H., Atashi H., Zamani P. and Bottema C. (**2011**). High Resolution Melting as an Alternative Method to Genotype Diacylglycerol O-acyltransferase 1 (DGAT1) K232A Polymorphism in Cattle // Czech Journal of Animal Science. 56(8): 370-376.

[18] Rashydov A.N., Spiridonov V.G., Konoval O.N. and Melnychuk M.D. (**2010**). Identification of Allele Variants of Cattle Milk Productivity Genes using PCR and the Anti-Primer Method // Cytology and Genetics. 44(5): 272-275.

[19] Tyulkin S.V., Vafin R.R., Zagidullin L.R., Akhmetov T.M., etc. (**2018**). Technological Properties of Cows Milk with Different Genotypes of Kappa-Casein and Beta-Lactoglobulin // Foods and Raw Materials. 6(1): 154-162. doi: 10.21603/2308-4057-2018-1-154-162

[20] Gaudet M., Fara A.G., Beritognolo L., Sabatti M. (**2009**). Allele-specific PCR in SNP Genotyping // Methods Mol. Biol. 578: 415-424. doi: 10.1007/978-1-60327-411-1_26

[21] Turovskaya S.N., Galstyan A.G., Radaeva I.A., Petrov A.N., Illarionova E.E., Ryabova A.E., Assembayeva E.K., Nurmukhanbetova D.E. (**2018**). Scientific and practical potential of dairy products for special purposes // News «Series of Geology and Technical Sciences». N 6. P. 16-22. ISSN 2224-5278. https://doi.org/10.32014/2018.2518-170X.31

[22] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

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UTILIZATION OF HEAT POWER INDUSTRY WASTE IN THE FORM OF BINDING COMPOSITE MATERIALS IN KYRGYZSTAN

Abstract. This paper discusses the urgent problem of expanding the raw material base of the construction industry using fuel slags in cements. The influence of various methods of preparation and introduction of fuel slags on the basic properties of composite cementing materials was evaluated. It is shown how the properties of the composite cement-slag binder vary depending on the application method and the activation degree of the slag.

Key words: technogenic raw material; ash and slag mix; mixing; grinding; composite binding material; glass phase; hydraulic activity; chemical and mineralogical composition; dispersability; water demand; strength.

One of the research priorities in the development of the Kyrgyz Republic is the rational use of natural resources.

For the construction industry, the most promising resource and energy saving solution is the integrated use of affordable, cheap local raw materials, which include industrial waste such as ash and slag of thermal power plants that are in huge quantities accumulated in dumps, causing significant damage to the environment.

If the use of ash and slag wastes (ASW) in the developed countries is 50-90%, in Central Asian countries this figure is less than 4%.

In the city of Bishkek a huge stockpiling of ash and slag wastes, as well as wet ash discharge, fly ash and sulfogypsum were accumulated, which are formed as a result of desulfurization of flue gases. Utilization of waste from thermal power plants is of considerable interest both in solving the environmental problem and for the economic efficiency of the enterprise.

The research aim: development of gypsum binders from waste from Bishkek TPP.

Materials and methods. Sulfogypsum, which is formed as a result of desulfurization of flue gases, is characterized by a specific surface area (S = 2800-3000 cm^2/g); by the content of $CaSO_4 \cdot 2H_2O$ – 93-95%; $CaCO_3$ – 1.6-1.7%; pH 4.5-9; ρ_{bulk} – 520-530кг/м^3; ρ_{true} – 2.35-2.37 g/cm^3; W = 20-27%. It can be attributed to high-quality gypsum raw materials of Class I and the production of gypsum binders on their basis is of undoubted interest.

The chemical composition of the HPP waste is given in the table 1.

Table 1 – Chemical composition of raw materials

No.	Oxide content, %									
	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	SO_3	Na_2O	K_2O	П.п.п.
Sulfogypsum	0.09	0.23	0.36		55.72	0.76	0.07	–	–	41.55
Fly ash	55.4	23.15	4.30		2.18	1.35	1.08	1.72	2.08	4.94
Wet ash discharge	52.0	21.58	0.97	0.97	6.47	1.14	0.21	0.9	1.7	12.13
Cement of KCSP	22.44	4.65	4.11		65.59	1.75	0.33	–	–	0.2
Sand from Vassiliyevskiy	68.72	14.21	3.24		3.25	2.68	2.61	–	–	

The laboratory of Kyrgyz State N. Issanov University of construction, transport and architecture obtained the construction gypsum based on sulfogypsum. Gypsum was cooked at a temperature of 150 °C with an exposure time of 90 minutes at the indicated temperature; time of temperature rise - 40 min.

The test of construction gypsum was carried out in accordance with GOST (National Standards) 23789-79. According to physical and mechanical properties, the construction gypsum from sulfogypsum corresponds to grade G-4-B-III (table 2).

Table 2 – Physical and mechanical properties of the construction gypsum from sulfogypsum

Temperature of burning, °C	Grinding fineness 02, %	Standard consistency, %	Setting time, min		Sample density, g/cm^3	Strength limit after 2 hours in MPa	
			start	end		R_{flex}	R_{rupt}
150	0	68	12	16	1.64	1.86	4.2

Since the construction gypsum based on sulfogypsum has a low resistance to environmental influences and a sharp decrease in strength in moistening, the fillers and additives were modified to improve the water resistance of gypsum binders. As a basic component of the binder, G-4 gypsum, obtained from sulfogypsum, was used.

Ash of Bishkek TPP with a specific surface of S_{spec} = 350-400 m^2/kg was used as a filler in gypsum binders. They have pozzolanic activity as they contain clay-firing products: amorphous clayey material such as metakaolinite, amorphous SiO_2, Al_2O_3, Fe_2O_3 and aluminosilicate glass. High hydraulic activity of the amorphous clay substance is associated with its high specific surface, which is created as a result of the decomposition ($Al_2O_3 \cdot 2SiO_2$) into amorphous alumina and silica.

The thermally treated quartz which is contained in the ash, due to increased solubility, interacts with calcium hydroxide. The higher the concentration of hydroxide in the liquid phase is, the more active the ash is.

According to the characteristics of the ash activity modulus $M_0 = CaO+MgO/SiO_2+Al_2O_3 = 0.045$, the alumina module $p = Al_2O_3/Fe_2O_3$, the modulus of activity $M_a = Al_2O_3/SiO_2 = 0.41$, it can be inferred that for $M_0<1$, the ash has increased activity. In this case, the higher the activity modulus is, the faster the ash hardens in the grinded state. An important feature of ash is its high intensive grinding capacity.

Lime of the 1st grade and portland cement were used to activate low-calcium acid ash. Lime is characterized by the content of CaO+MgO within 92% and the content of unhydrated, unslaked particles is 0.5%.

The addition of K_2SO_4 together with lime in the composition of the binder causes high concentrations of potassium and sulfate ions. Calcium sulphate and potassium sulfate can be isolated as a double salt, as a result of recrystallization of which the spatial structure of $CaSO_4 \cdot 2H_2O$ is formed. Phase transformations of crystalline hydrate new-growths stimulate a change in the kinetics of expansion of the system and a general decrease in deformation.

Research findings and their discussion. During the research, a 4-factor experiment was carried out according to the B_4 plan, consisting of 24 experimental points. Each of the prescription factors performs a certain role in the formation of the structure of the gypsum binder and changed at three levels: X_1 - ash (0..15 ... 30%); X_2-lime (0 ... 2 ... 4%); X_3-K_2SO_4 (0 ... 1.5 ... 3.0%); X_4-cement (0 ... 5 ... 10%); the rest is gypsum-waste of TPP.

As the main parameters of gypsum binder are selected: Y_1 - Normal thickness, Y_2 initial setting period, min .; %; Y_3 - end of setting, min .; Y_4 - $R_{bend.}$, MPa; Y_5 - $R_{compres.}$, MPa; Y_6-$R_{compress.\ of\ wet}$, MPa; the softening factor is Y_7.

Optimization criteria Kp ≥ 0,6 and strength $R_{dry\ compres} \geq 10$ MPa.

Table 4 – Experiment plan B_4

No.	Encoded variables				Experiment results							
	x_1	x_2	x_3	x_4	Y_1 НГ, %	Y_2 Average setting start (min)	Y_3 Average set end:min	Y_4 $R_{bend.}$ MPa	Y_5 $R_{dry\ compr}$ MPa	Y_6 $R_{wet\ compr.}$ MPa	Y_7 K_p	Y_8 W, %
1	+	+	+	+	68	6.21	7.75	1.13	5.68	2.89	0.51	34.5
2	+	+	+	–	65	6.33	8.0	1.25	5.76	2.76	0.48	37.9
3	+	+	–	+	67	14.55	20.25	1.67	6.88	3.50	0.51	36.9
4	+	+	–	–	67	19.75	29.25	1.97	5.88	2.64	0.45	38.8
5	+	–	+	+	70	2.81	3.60	1.37	5.28	2.48	0.47	42.2
6	+	–	+	–	68	2.25	2.83	1.33	5.12	1.28	0.25	43.9
7	+	–	–	+	67	10.16	17.58	2.55	7.68	4.37	0.57	31.0
8	+	–	–	–	67	10.75	19.16	2.47	7.0	3.92	0.56	30.8
9	+	+	+	+	67	5.75	7.41	2.51	10.52	5.04	0.48	34.9
10	–	+	+	–	68	5.75	7.48	2.16	8.72	3.31	0.38	34.9
11	–	+	–	+	70	15.16	19.50	2.8	10.26	4.51	0.44	38.2
12	–	+	–	–	67	13.50	19.91	2.93	13.24	6.22	0.47	35.4
13	–	–	+	+	67	2.08	3.58	2.45	10.44	5.01	0.48	35.5
14	+	–	+	–	65	2.20	2.95	2.65	8.84	4.98	0.46	43.1
15	–	–	–	+	63	8.83	15.08	3.32	10.7	6.54	0.61	33.8
16	–	–	–	–	60	12.66	18.83	2.81	8.56	4.24	0.48	39.6
17	+	**0**	**0**	**0**	70	4.83	8.75	1.69	8.6	5.16	0.6	32.3
18	–	**0**	**0**	**0**	62	6.50	11.10	2.64	10.32	5.26	0.51	34.0
19	**0**	+	**0**	**0**	63	8.86	13.93	1.84	8.88	4.97	0.56	36.8
20	**0**	–	**0**	**0**	63	3.25	4.58	2.35	22.8	14.82	0.65	34.2
21	**0**	**0**	+	**0**	68	5.03	6.11	1.9	8.68	5.2	0.60	35.9
22	**0**	**0**	–	**0**	70	14.08	22.18	2.65	8.72	5.23	0.60	40.6
23	**0**	**0**	**0**	+	68	6.86	8.58	2.28	10.12	6.27	0.62	39.5
24	**0**	**0**	**0**	–	67	6.83	8.33	2.29	11.0	6.71	0.61	32.3

Based on the results of the experiment, specifying the average error S and significance level $\alpha = 0.01$, the mathematical models of the properties of the gypsum binder were obtained.

Y_2 - Start of the setting, min.

$$\begin{aligned}(Y_2) = {} & 6.48 + 0.29\,x_1 - 0.82x_1^2 + 0.41x_1x_2 - 0.20x_1x_3 - 0.19\,x_1x_4 \\ & + 2.27\,x_2 - 0.43x_2^2 - 0.37x_2x_3 - 0.02\,x_2x_4 \\ & - 4.502\,x_3 + 3.072\,x_3^2 + 0.517\,x_3x_4 \\ & - 0.423\,x_4 + 0.362\,x_4^2\end{aligned} \quad (1)$$

Y_3 - End of setting, min.

$$\begin{aligned}(Y_3) = {} & 9.694 + 0.629\,x_1 + 0.231\,x_1^2 + 0.514\,x_1x_2 - 0.76\,x_1x_3 - 0.404\,x_1x_4 \\ & + 2.516\,x_2 - 0.39\,x_2^2 - 0.036\,x_2x_3 - 0.363\,x_2x_4 \\ & - 7.335\,x_3 + 4.451\,x_3^2 + 0.989\,x_3x_4 \\ & - 0.745\,x_4 - 1.239\,x_4^2\end{aligned} \quad (2)$$

Y_4 - $R_{bend.}$ Bending resistance, MPa

$$\begin{aligned}(Y_4) = {} & 2.209 + 0.491x_1 - 0.054x_1x_2 - 0.093\,x_1x_3 - 0.052x_1x_4 \\ & - 0.0169x_2 + 0.064x_2x_3 \\ & - 0.357x_3 - 0.006\,x_3x_4\end{aligned} \quad (3)$$

Y_5-$R_{dry\ compr.}$ MPa

$$(Y_5) = 12.133 - 1.873\,x_1 - 2.673\,x_1^2 - 0.317\,x_1x_2 - 0.085x_1x_3 - 0.05\,x_1x_4 - 0.589\,x_2 + 3.707\,x_2^2 - 0.082x_2x_3 - 0.302\,x_2x_4 - 0.549\,x_3 - 3.433\,x_3^2 + 0.165\,x_3x_4 + 0.191\,x_4 - 1.573x_4^2 \quad (4)$$

Y_7-K_{soft} - softening factor

$$(Y_7) = 0.633 + 0.005\,x_1 - 0.078\,x_1^2 + 0.022\,x_1x_2 - 0.011\,x_1x_3 + 0.006\,x_1x_4 - 0.014\,x_2 - 0.028\,x_2^2 + 0.034\,x_2x_3 - 0.014\,x_2x_4 - 0.032\,x_3 - 0.033\,x_3^2 + 0.012\,x_3x_4 + 0.031\,x_4 - 0.018\,x_4^2 \quad (5)$$

A preliminary analysis of the ES coefficients of the models (1, 2) of the setting time of the composite gypsum binder showed that the setting time is significantly accelerated with the addition of K_2SO_4, which indicates the crystallization effect. So for model (1) the setting start, the linear coefficient at factor x_3 was $b_3 = -4.502$. For the model (2), the end-of-setting, the linear effect is $b_3 = -7.335$.

Linear effects at the factor x_2 (lime) indicate an increase at the staart and end of the setting of the gypsum binder. For the model (1), $b_2 = + 2.271$, and for the model (2) $b_2 = + 2.516$, because lime reduces the solubility of gypsum, thereby prolonging the setting time.

The presence of ash (x_1) and cement (x_4) does not significantly affect the setting time of the gypsum binder ($b_1 = 0.289$ and $b_4 = -0.423$) and ($b_1 = 0.629$ and $b_4 = -0.745$).

Analysis of flexural and compressive strength models of gypsum binder (3, 4) showed that the presence of ash (x_1) and cement (x_4) should be at the optimal level ($b_{11} = -2.673$) and ($b_{44} = -1.573$). Their maximum content leads to a large utilization of ash, but results in a decrease in the strength of the binder. Increasing the amount of cement is not advisable, because it increases the amount of ettringite, which is formed during the hydration of cement. The content of lime additives (x_2) and K_2SO_4(x_3) should be optimized, as can be seen from the quadratic effects (b_{22} =3.707 и b_{33} = -3.433).

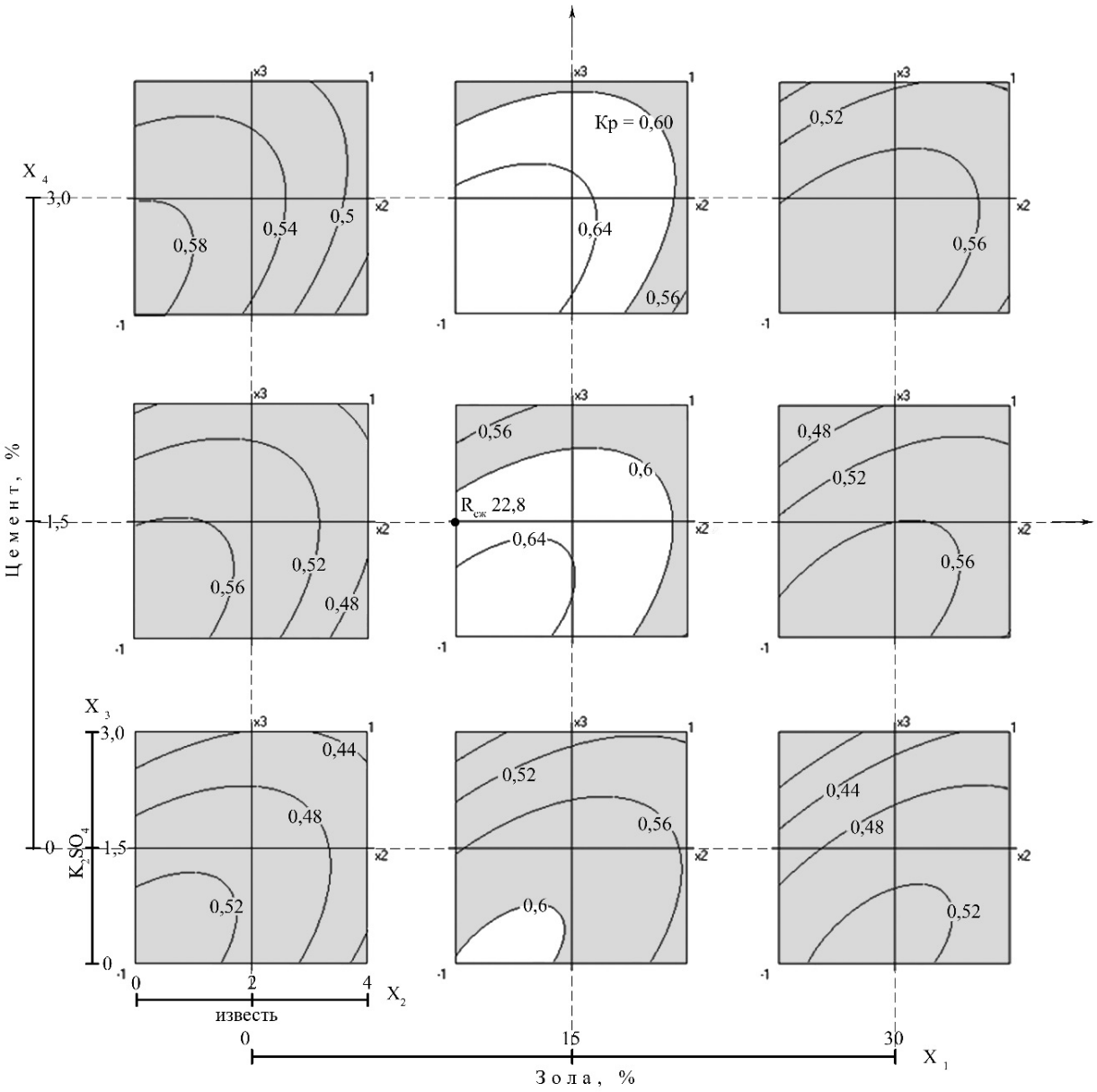
The Ks_{oft} factor of the softening agent (Y_7) of the gypsum binder is within the permissible range of $Ks_{oft} \geq 0.6$, provided that there is an ash additive ($b_1 = 0.005$), but in the optimal amount ($b_{11} = -0.078$). This fact shows the formation of insoluble compounds, as a result of the interaction of ash with calcium hydroxide, which contribute to an increase in water resistance. The optimal cement content also provides ($b_{44} = -0.018$) an increase in the water resistance of the gypsum binder ($b_4 = + 0.031$). To ensure the required K_{soft}, the lime (x_2) and K_2SO_4 (x_3) content is a prerequisite and depends on the amount of ash ($b_{12} = 0.022$, $b_{13} = -0.011$, $b_{14} = + 0.006$).

The softening coefficient of samples from gypsum as seen from the results of the experiment for all points of the plan varies between $0.25 \leq K_{soft} \leq 0.65$. According to the optimization conditions, $K_{soft} > 0.6$ is achieved if the optimum formulation of the constituent components is fulfilled: the amount of ash $X_1 = 15\%$, lime $X_2 = 1.5$ ... 2%, K_2SO_4 $X_3 = 1$ ... 1.5%, cement $X_4 = 1.5$ ... 3.0%.

In figure, it is clearly possible to observe an area where an increased value of the coefficient $K_{soft} > 0.6$ (an unpainted zone) is provided. Here it is necessary to adhere to the formula mentioned above.

Thus, studies have shown the utilization possibility of the ash in gypsum binders while maintaining the required quality indicators. Moreover, with the optimal amount of additive components, the strength characteristics and the softening factor increase.

To obtain waterproof gypsum binders with $K_{soft} \geq 0.6$ and strength $R_{dry\ compr.} \geq 10$ MPa, the following formula is recommended: fly ash 15 ... 22%; lime1.5 ... 2%; cement 1.5% and K_2SO_4 1.5%.



The isolines of the softening coefficient of samples from gypsum Y_7 (K_{soft}) = f(x_2, x_3) in nine points of the factor space x_1 and x_4

Conclusion:

- Sulphogypsum was obtained at the Bishkek TPP by desulfurizing industrial gases, which can be attributed to gypsum raw materials of grade I;
- Construction gypsum G4-B-III was obtained on the basis of sulfogypsum;
- To increase the water resistance of gypsum binders the experimental-statistical modeling has been conducted which revealed that the use of fly ash as a filler together with lime and K_2SO_4 promotes the regulation of the setting time (elongation), which is important in the technological plan. Growth of the K_{soft} and of the water absorption of gypsum stone shows an increase in water resistance of gypsum products due to the formation of insoluble hydrosilicates in the process of hydration of ash and clinker minerals of cement with lime.
- Waterproof modified gypsum binders can find application for the manufacture of products for various purposes.
- Within the framework of one enterprise, ash and sulfogypsum are recycled, which is economically feasible.

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ҚЫРҒЫЗСТАННЫҢ ЖЫЛУ ЭНЕРГЕТИКАСЫНЫҢ ҚАЛДЫҚТАРЫН КОМПОЗИЦИЯЛЫҚ БАЙЛАНЫСТЫРҒЫШ ЗАТТАРДА ПАЙДАЛАНУ

Аннотация. Мақалада цементтердегі отын шлактарын пайдалана отырып, құрылыс индустриясының шикізат базасын кеңейтудің өзекті мәселесі туралы айтылады. Композияциялық байланыстырғыштардың негізгі сипаттарына отын шлактарын дайындау және енгізу түрлерінің тәсілдеріне баға жасалды. Шлакты енгізу тәсілі мен белсендіру дәрежесіне қарай композициялық цементті-шлакты байланыстырғыштың сипатының қалай өзгеретіндігі анықталды.

Түйін сөздер: техногендік шикізат; күл қоспасы; араластыру; ұсақтау; композициялық байланыстырғыш; шыны фазасы; гидравликалық белсенділік; химиялық-минералдық құрам; дисперсия, су сұранысы, төзімділік.

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ИСПОЛЬЗОВАНИЕ ОТХОДОВ ТЕПЛОЭНЕРГЕТИКИ КЫРГЫЗСТАНА В КОМПОЗИЦИОННЫХ ВЯЖУЩИХ ВЕЩЕСТВАХ

Аннотация. Статья посвящена актуальной проблеме расширения сырьевой базы строительной индустрии за счет использования топливных шлаков в цементах. Проведена оценка влияния различных способов подготовки и введения топливных шлаков на основные свойства композиционных вяжущих. Показано как изменяются свойства композиционного цементно-шлакового вяжущего в зависимости от способа введения и степени активизации шлака.

Ключевые слова: техногенное сырье; золошлаковая смесь; смешение; измельчение; композиционное вяжущее; стеклофаза; гидравлическая активность; химико-минералогический состав; дисперсность, водопотребность, прочность.

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REFERENCES

[1] Alaskhanov A.Kh., Murtazaev S.-A.Yu., Chernysheva N.V. (2013). Use of ash and slag mixtures of thermal power plants for the production of composite gypsum binders // Ecology and industry of Russia. July 2013. P. 26-29.

[2] Feronskaya A.V. (2008). Gypsum in low-height construction // Under the general ed. A. V. Feronskaya. M.: ASV Publishing House, 2008. 240 p. M.: ASB, 2008. 240 p.

[3] Dvorkin L.I., Dworkin O.L. (2007). Building materials from industrial waste. Rostov-na-Donu: Phoenix, 2007. 368 p.

[4] Kokubu M. (1972). Ash and ash cements // Proceedings of the International Congress on Chemistry of Cement. M., 1972.

[5] Koroviakov V.F. (2005). Increase of water resistance of gypsum waterproof binders and expansion of their application areas // Building materials, equipment, technologies of the XXI century, 2005. N 3. P. 14-17.

[6] Ratinov V.R. (1984), doctor of chemical sciences (MADI), Ivanicii V.V., candidate of technical sciences, D.I. Stekaov, engineer. (P.P. Budnikov SRI - VNIIstrom). Building materials. November 1984. N 11(359).

[7] Canadian J. // Civil Engineering. 1987. Va: 14. N 5. P. 667- 682.

[8] Wirsching F. (1983). Chemische Technologie. Band 3. Gips. Carl Hanser Verlag München, Wien, 1983.

[9] FGD Gypsum: quality criteria and analysis methods // www.eurogipsum.org

[10] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

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COPPER POWDERS FORMATION IN THE CATHODIC AND ANODIC HALF-PERIODS WITH INDUSTRIAL ALTERNATING CURRENT

Abstract. For the first time, an installation was created for producing copper powders in the anodic and cathodic half-periods of industrial alternating current with a frequency of 50 Hz. This device consists of two electrolytic cells interconnected in parallel, in each electrolyzer there are two copper electrodes. Two diodes are also included in the electrochemical circuit to allow current flowing in opposite directions. The influence of electrodes current density, sulfuric acid concentration, copper ions, on current output of copper powder formation in each cell was investigated. It was established that the current output increases within the current density from 2000-8000 A/m^2 and decreases with further increase of this parameter. When sulfuric acid concentration was 100 g/l and copper ions concentration was 15 g/l, the maximum current output of powder in electrolyzes was 50.1-53.3%, and the total current output exceeded 100%.

Using a JSM-661 LV scanning electron microscope, the shape and size of obtained powders were investigated. On the basis of the conducted studies and captured oscillograms, the mechanism for copper powders formation in the anodic and cathodic half-cycles of alternating current was established. For the first time it was shown that the proposed installation allows to obtain copper powders in two half periods of alternating current. It was established that at the same time ultrafine metal powders with particle sizes of 1.0-1.5 microns had been formed.

Keywords: alternating current, copper powders, titanium, diode, electrode, electrolyte, cathode and anodic half-periods, oscillogram.

Electrochemical reactions mechanism, which usually occurs in the electrodes, is very complex. Electrochemical reactions course depends on an electrolyte composition and its temperature, current density in the electrode and their nature, hydrodynamic conditions in the electrolyte and other parameters [1]. For example, when the concentration of copper (II) ions is high and the current density at the cathode is not higher than one electrode surface, a layer of copper is formed. It is known that at a low concentration of metal ions, and a high surface density of the cathode (i.e., in case of exceeding the limiting current densities), copper (II) ions are restored and precipitate to form small powder particles [2].

In recent years, many scientific studies have been carried out to obtain ultrafine and nano-sized copper powders [3-15].

With polarization using unsteady current, the nature and nature of the reactions that take place on the cathode surface cannot be fully determined. Our previous studies have shown the possibility of obtaining various metal compounds with polarization by industrial alternating current with a frequency of 50 Hz, and also demonstrated the ability to manufacture dispersed copper powders [16, 17]. In our earlier studies, a pair of titanium electrode with a small surface area and a large-area copper electrode was collected for the first time, and the possibility of producing ultrafine copper powders in sulfuric acid copper (II) solution with polarization using industrial alternating current was shown for the first time. In this case, in each cathode half-cycle of alternating current, copper ions can be restored on the surface of the titanium

electrode polarized at high current densities, and as a result copper powders are formed. At that moment, when a copper electrode with a larger area is in the anodic half-period, copper (II) ions dissolve. When the titanium electrode is under alternating current in the anode half-period, its surface is a film of titanium oxide (Ti_xO_y), which has semiconductor properties, which prevents the passage of electric current in this direction. These processes are periodically repeated on the surface of the electrodes with a frequency of 50 Hz.

Experiments and process mechanism. In the proposed research work, many scientific ideas were filtered out and a special facility was assembled for the first time. The possibility of obtaining copper powder in its cathode and in the anodic half-periods during the polarization of industrial alternating current using this device is considered. A schematic diagram of this setup is shown in figure 1 below.

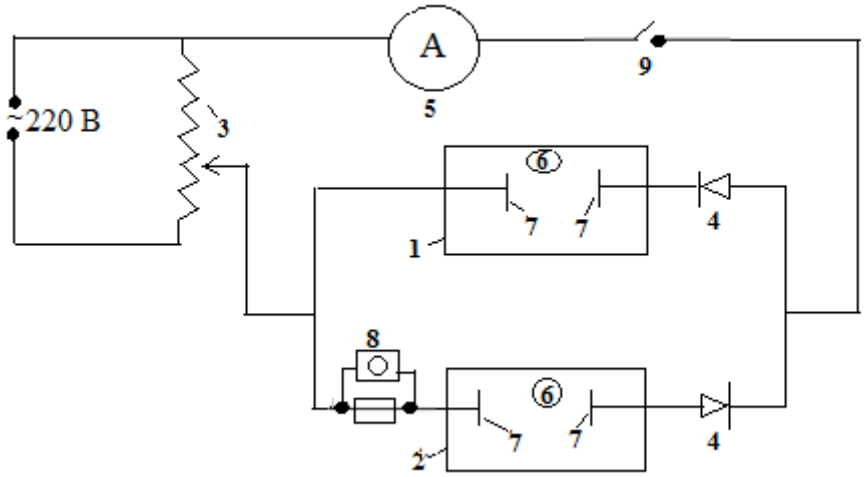


Figure 1 – Schematic circuit diagram of the installation for obtaining copper powder in its two periods by polarization of alternating current: 1 – first electrolyzer, 2 – second electrolyzer, 3 – laboratory transformer, 4 – diodes, 5 – amperometer, 6 – electrolyte, 7 – copper electrodes, 8 – oscillograph, 9 – key

This installation is a combination of two electrolyzers parallel to each other (1.2) from laboratory transformer (3), which allows regulating the alternating voltage (power) of two diodes (4) of the brand KD 213 A, placed in the opposite direction from each the other in the electrical circuit, and an ammeter (5) indicating the amount of current passing through the circuit. Sulfuric copper (II) electrolyte (6) is poured into each electrolyzer and two copper electrodes (7) are installed.

A known amount of alternating current, issued by the laboratory transformer, is divided equally into two electrolysers, which are installed parallel to each other. In general, the alternating current passing through an electrochemical circuit is transmitted 50 times per second in one direction and the same amount, therefore, in the opposite direction. Since the diodes connected to the circuit are connected to each other, the alternating current passes through the first electrolyzer in its half-period, and through the second electrolyzer in its half period.

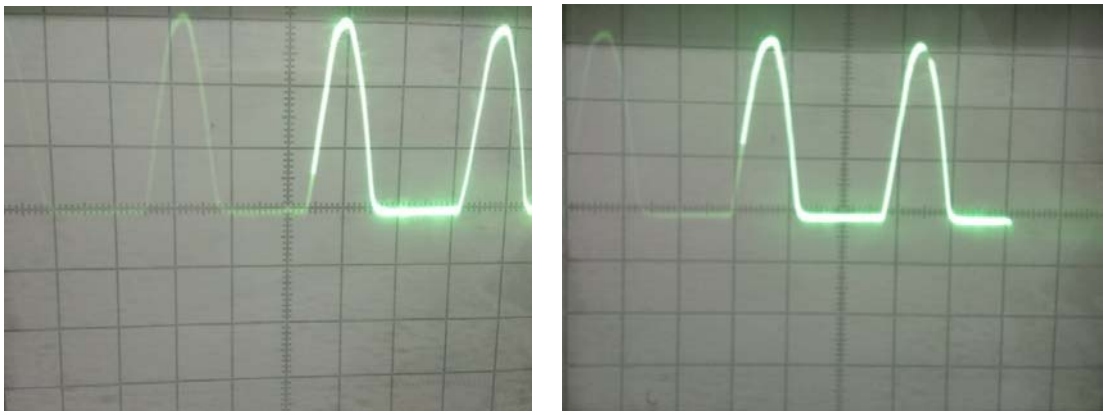
An oscillogram of currents passing through two electrolysers was recorded during the polarization of alternating currents. The oscillogram of currents passing through each electrolysis circuit shows the passage of a pulsed current using electrodes (figure 2). Therefore, the electrodes are polarized in turn by anodic and cathodic pulsed currents.

As shown in Figure 1, if in the first electrolyzer on the right side in one half period the copper electrode serves as a cathode, then in the second half period in the second electrolyzer the copper electrode located on the left side is considered to be a cathode, as a result copper reduction proceeds on them:

$$Cu^{2+} + 2e^{-} \rightarrow Cu^{0}. \quad (1)$$

Since the current density in the cathodes is higher than the limiting current density, copper (II) ions are oxidized to form copper powders.

The electrolysis was carried out using the above installation. The main goal is to obtain copper powders in cathodic and anodic half periods by polarization with alternating current.



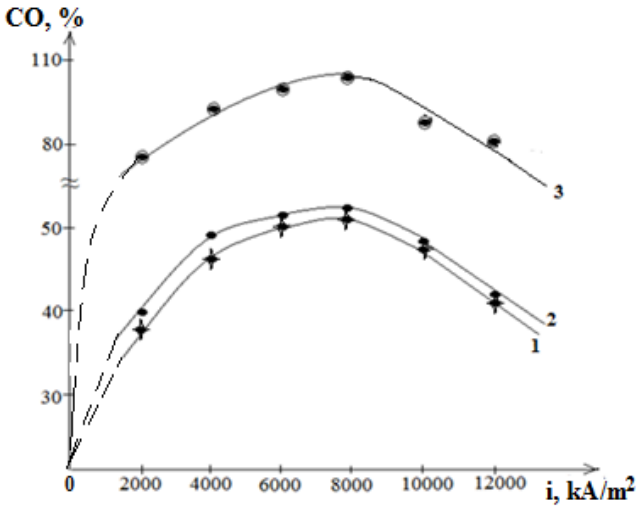
i = 600 A/m^2; H_2SO_4 – 100 g/l; Cu (II) – 15 g/l; t = 25 °C

Figure 2 – Oscillogram of the amplitude of the current passing through each circuit of the electrolyzer when polarized with alternating current

Two electrolysis are filled with copper (II) solution with dilute sulfuric acid, their concentration: H_2SO_4 – 100 g/l, Cu (II) – 15 g/l. Copper electrodes area are the same (13.68 cm^2). Our preliminary studies have shown that copper powders are formed in both electrolysers. In our first study, we investigated the effect of current density (2000–12000 A/m^2) on the formation of copper powder on a copper electrode. The current output during the formation of copper powders in each electrolyzer was calculated for the cathode half-period with alternating current.

As a rule, copper powder should be formed of the same size in both electrolyzers, however, due to errors in the distances between the electrodes in each cell and the inability to reproduce the ideal electrode areas, the experimental results show that small deviations are observed.

Experimental procedure. The research results showed that while current density increasing on the electrodes to a value of 8000 A/m^2, the current efficiency during copper powder formation increases, but a subsequent increase in the values leads to a decline (figure 3). The decrease in current efficiency during copper powders formation at high densities can be explained by the reaction of additional evolution of gaseous hydrogen. For example, when electrodes current density is 2000 A/m^2, the current efficiency of copper powders formed in the first electrolyzer is 38.0%, in the second – 40.1%, and thus the amount of metal powders deposited in two electrolyzers can be considered about the same, as it should be. While the current density in both electrolyzers was 8000 A/m^2, the current efficiency of the powders in the electrolyzer was 50.1 and 52.3%, respectively.



H_2SO_4 – 100 g/l; Cu (II) – 15 g/l; τ = 30 min; t = 25 °C

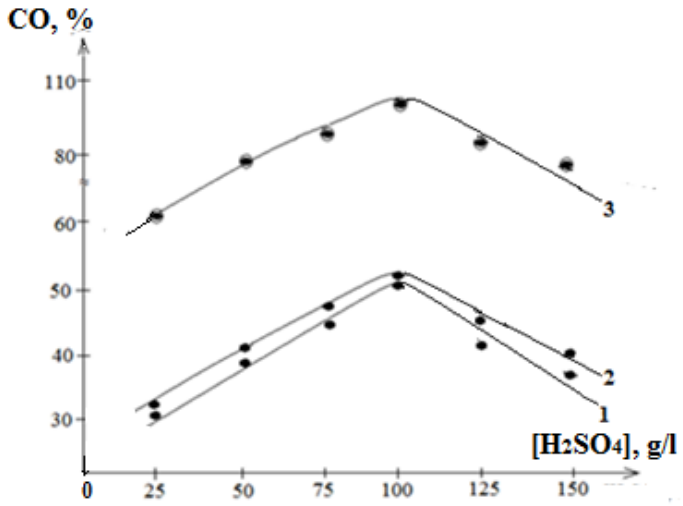
Figure 3 – The effect of current density on copper electrodes polarized with alternating current on the current output during copper powders formation: 1 – first electrolyzer; 2 – second electrolyzer; 3 – in two electrolyzers

If you pay attention, the total current efficiency of copper powders formed in two electrolyzers exceeds 100%. This phenomenon can be explained by the reaction of chemical disproportionation:

$$2Cu^{+} \rightarrow Cu^{0} + Cu^{2+}. \quad (2)$$

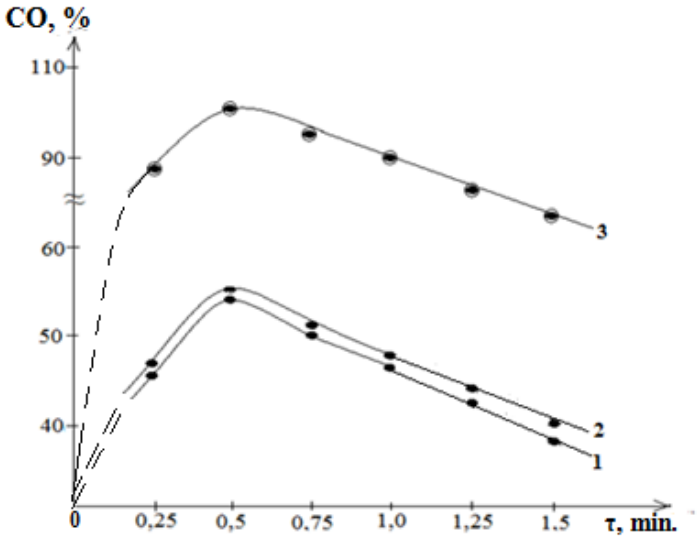
Our previous studies [18] showed that the potential fluctuation of copper electrode leads to the formation of copper powders based on reaction 2.

At the proposed facility, we investigated the effect of sulfuric acid concentration in the electrolyte within the range of 25–200 g/l on copper powders formation. When increasing the amount of sulfuric acid in the electrolyte to 100 g/l, the current efficiency of the formed copper powders increases slightly, and then this indicator decreases (figure 4). Current efficiency increasing can be explained by an increase in the conductivity of the electrolyte current, and a decrease due to the re-dissolution of the precipitated copper powders and a decrease in the high voltage of hydrogen ions, which can be explained by an increase in the release of gas.



i = 8000 A/m^2, [Cu^{2+}] – 15 g/l; τ = 30 min; t = 25 °C

Figure 4 – The influence of sulfuric acid concentration on current output of copper powders formation during polarization with alternating current: 1 – first electrolyzer; 2 – second electrolyzer; 3 – in two electrolyzers



i_{Ti} = 8000 A/m^2; i_{Cu} = 150 A/m^2; H_2SO_4 – 100 g/l; [Cu^{2+}] – 15 g/l; t = 25 °C

Figure 5 – The influence of electrolysis duration on current output of copper powders formation during polarization with alternating current: 1 – first electrolyzer; 2 – second electrolyzer; 3 – in two electrolyzers

It should be noted when sulfuric acid concentration in the solution was 100 g/l, the current efficiency in the first electrolysis was 49.1%, in the second – 52.3%, while the total value of copper powders current efficiency in both electrolyzers amounted to 100.4%.

The effect of electrolysis duration on copper powders formation was investigated. The results of the study showed that copper powders deposition up to 0.5 hours increased the current efficiency, however, a further increase leads to deterioration (figure 5). Current efficiency decreasing is associated with a decrease in the concentration of copper (II) ions in the electrolyte and gaseous hydrogen proportion increasing.

Conclusions. To determine the shape and size of copper powders formed during electrolysis, photographs were taken of them on the latest version of a JSM-6610 LV scanning electron microscope (figure 6). During the course of electrolysis and a current density of 4000 A/m^2, metal powders with a circular shape of 1–1.5 μm were found, while at higher densities, the formation of grouped together ultrafine copper powders, such as dendrites of ~ 1 μm size, was found.

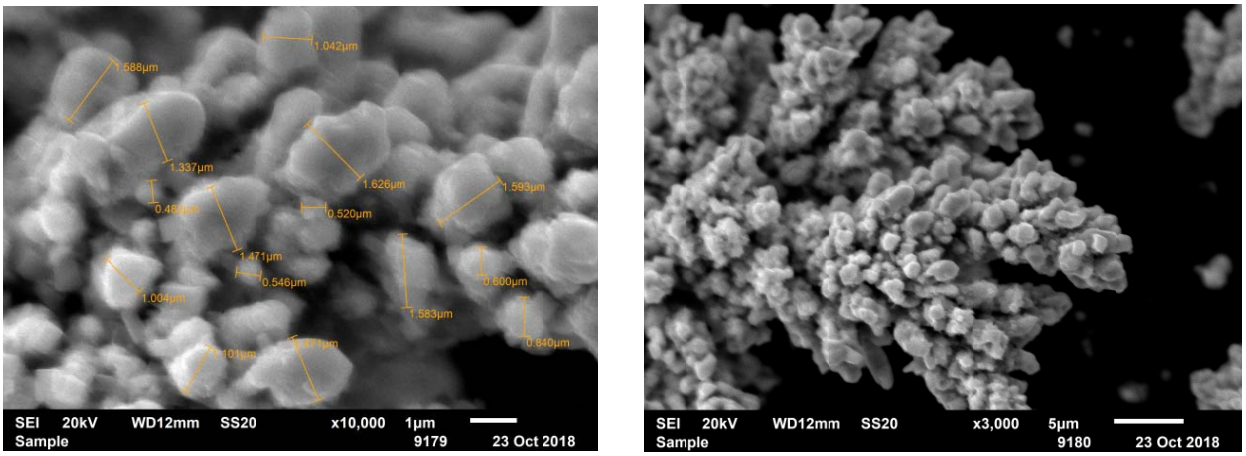


Figure 6 – Micrographs of electron microscopy of copper powder precipitated during electrolysis

Thus, for the first time, it was shown that it is possible to obtain copper powders with a high current output on the anodic and cathodic half-periods at an industrial alternating current with a frequency of 50 Hz on a special device recommended by us. In this case, copper powders formation with a dispersed particle size in the region of 1–1.5 μm was established.

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ӨНДІРІСТІК АЙНЫМАЛЫ ТОКТЫҢ АНОДТЫҚ ЖӘНЕ КАТОДТЫҚ ЖАРТЫЛАЙ ПЕРИОДТАРЫНДА МЫС ҰНТАҚТАРЫНЫҢ ТҮЗІЛУІ

Аннотация. Алғаш рет мыс ұнтақтарын жиілігі 50 Гц-ке тең айнымалы токтың анодтық және катодтық жартылай периодтарында алуға арналған кондырғы жасалды. Қондырғы бір-бірімен параллель түрде жалғанған екі электролизерден құралған, әрбір электролизерде екі-екіден мыс электродтары орналастырылған. Сонымен катар электрохимиялық тізбекке екі диод косылған, олар токтың қарама-қарсы бағытта жүруін қамтамасыз етеді. Әрбір электролизерде түзілетін мыс ұнтақтарының ток бойынша шығымына ток тығыздығының, күкірт қышқылының және мыс иондарының концентрациясының әсері зерттелінді. Ток бойынша шығым ток тығыздығының 2000–8000 А/м^2 аралығында артатыны және бұл параметрдің ары қарай жоғарылауында азаятыны көрсетілді. Күкірт қышқылының концентрациясы 100 г/л-ге және мыс иондарының

концентрациясы 15 г/л құрағанда, электролизерлерде түзілетін ұнтақтың максималды ток бойынша шығымы 50,1–53,3%, ал жалпы ток бойынша шығым 100%-тен асады.

JSM-661LV маркалы сканирлеуші электрондық микроскоптың көмегімен алынған ұнтақтардың формалары және размерлері анықталды. Жүргізілген зерттеулер және түсірілген осциллограммалар негізінде айнымалы токтың анодтық және катодтық жартылай периодтарында мыс ұнтақтарының түзілу механизмі анықталды. Алғаш рет ұсынылған кондырғыда мыс ұнтағын айнымалы токтың екі жартылай периодтарында алу мүмкіндігі көрсетілді. Бұл кезде бөлшек размерлері 1,0–1,5 мкм құрайтын металл ұнтақтарының түзілетіні анықталды.

Түйін сөздер: айнымалы ток, мыс ұнтақтары**,** титан, диод, электрод, электролит, анодтық және катодтық жартылай периодтар, осциллограмма.

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ФОРМИРОВАНИЕ ПОРОШКОВ МЕДИ В АНОДНОМ И КАТОДНОМ ПОЛУПЕРИОДАХ ПРОМЫШЛЕННОГО ПЕРЕМЕННОГО ТОКА

Аннотация. Впервые создана установка для получения порошков меди в анодном и катодном полупериодах промышленного переменного тока с частотой 50 Гц. Установка состоит из двух электролизеров, соединенных между собой параллельно, в каждом электролизере расположены по два медных электрода. В электрохимическую цепь также включены два диода, обеспечивающие протекание тока в противоположных направлениях. Исследовано влияние плотности тока на электродах, концентрации серной кислоты, ионов меди, на выход по току образования порошка меди в каждом электролизере. Установлено, что выход по току увеличивается в пределах плотности тока от 2000–8000 А/м^2 и уменьшается при дальнейшем повышении данного параметра. При концентрации серной кислоты, равной 100 г/л и концентрации ионов меди 15 г/л, максимальный выход по току образования порошка в электролизерах составляет 50,1–53,3%, а общий выход по току превышает 100%.

С помощью сканирующего электронного микроскопа марки JSM-661LV исследованы форма и размеры полученных порошков. На основании проведенных исследований и снятых осциллограмм установлен механизм образования порошков меди в анодном и катодном полупериодах переменного тока. Впервые показано, что предложенная установка позволяет получить порошки меди в двух полупериодах переменного тока. Установлено, что при этом формируются ультрадисперсные порошки металла с размерами частиц 1,0–1,5 мкм.

Ключевые слова: переменный ток, порошки меди, титан, диод, электрод, электролит, анодный и катодный полупериоды, осциллограмма.

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REFERENCES

[1] Kiparisov S.S., Libenson G.A. Poroshkovaya metallurgiya. M., 1972. 528 p.

[2**]** Bayeshov A., Bayeshova A.K., Baeshova S.A. Elektrohimiya. Qazaq universiteti, 2014. 316 p.

[3] Komarnickij G.V., Lopatin V.YU., Libenson G.A. Processy poroshkovoj metallurgii. V 2-h t. Vol. 1. M.: izd-vo Misis, 2001.

[4] German R. Poroshkovaya metallurgiya ot A do YA. Izd-vo Intellekt, 2009. 336 p.

[5] Simenyuk G.Yu., Obrazcova I.I., Eremenko N.K. Patent 2426805 Ros. Federaciya. Sposob polucheniya nanodispersnogo poroshka medi // Opubl. 20.08.2011. Byul. №3. 13 p.

[6] Dorofeev Yu.G., Lipkin M.S., Naumenko A.A., Rybalko E.A., Sirotin P.V., Ivashin I.N., Lipkin V.M. Poluchenie mednyh poroshkov iz ammiakatnyh ehlektrolitov i ih svojstva // Izvestiya vysshih uchebnyh zavedenij. Poroshkovaya metallurgiya i funkcional'nye pokrytiya. 2012. N 3. P. 3-7.

[7] Rybalko E.A., Lipkin M.S., Naumenko A.A., Dorofeev Yu.G., Lipkin V.M. Patent № 2469111 Ros. Federaciya. Sposob polucheniya mednyh poroshkov iz med'soderzhashchih ammiakatnyh othodov // Opubl. 10.12.2012. Byul. № 34. 6 p.

[8] Rybalko E.A. Elektrohimicheskoe poluchenie ul'tradispersnyh mnogokomponentnyh poroshkov v processah utilizacii med'soderzhashchih materialov: dis. kand. tekhn. nauk. Novocherkassk, 2013. 145 p.

[9] Vnukov A.A. Osobennosti polucheniya mednyh ehlektroliticheskih poroshkov s povyshennym soderzhaniem v nih nanofrakcij // Vestnik HNADU. 2010. N 51. 25 p.

[10] Ageev E.V. Vozmozhnost' pererabotki mednyh othodov v poroshki ehlektroehrozionnym dispergirovaniem // Tekhnicheskie nauki – ot teorii k praktike. N 32. 55 p.

[11] Baimbetov B.S. i dr. Patent № 2022717 Ros. Federaciya. Sposob polucheniya mednogo poroshka ehlektrolizom iz sul'fatnyh ehlektrolitov i ustrojstvo dlya ego osushchestvleniya // Opubl. 15.11.1994, Byul. № 16. 3 p.

[12] He W., Duan X.C., Zhu L. Characterization of ultrafine copper powder prepared by novel electrodeposition method // J. Centr. South Univ. Technol. 2009. Vol. 16. P. 708-712.

[13] Nekouci R.K., Rashehi F., Amadeh A.A. Using design of experiments in synthesis of ultra-fine copper particles by electrolysis // Powder Technol. 2013. Vol. 237. P. 165-171.

[14] Pavlovie M.G., Pavlovie Lj., Maksimovie V., Nikolie N., Popov K. Characterization and morphology of copper powder particles as a function of different electrolytic regimes // Int. J. Electrochem. Sci. 2010. Vol. 5. P. 1862-1878.

[15] Wang M.Y., Wang Z., Guo Z.C. Preparation of electrolytic copper powders with high current efficiency enhanced by super gravity field and mechanism // Trans. Nonferrous Met. Soc. China. 2010. Vol. 20. P. 1154-1160.

[16] Baeshov A.B. Elektrohimicheskie processy pri polyarizacii nestacionarnymi tokami // Izvestiya NAN RK. Seriya himii i tekhnologii. 2011. N 2. P. 3-23.

[17] Baeshov A. Elektrohimicheskie metodyi izvlecheniya medi, halkogenov i sinteza ih soedineniy. «Nauka» KazSSR, 1990. 107 p.

[18] Bayeshov A. Issledovanie elektrodnyh processov pri elektrorafirnirovanii medi: kand. dis. Alma-Ata, 1977. 124 p.

[19] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[20] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[21] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[22] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[23] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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GRAPHEN AND NATURAL FORMATIONS

Abstract. It is well known that a great deal of metallic phases occurs in the ultradispersed state. The extracted phases with a low gross content are scattered over the vast occupied area. Large deposits of Kazakhstan are related to this type of ore-bearing formations.

Studies of the natural objects are complicated manyfold by heterogeneity of substances and the staging of the ongoing processes. In our studies, as reference matter we adopt the solid natural carbon substances, synthetised in various chemical processes running in compliance with strict rules of chemical reactions under given thermodynamic conditions. The natural carbon substance, as a rule, exists in a whole range of probable phases, often having the film-planar structure habit. Rock transformation (squeezing) results in curving film-lamellar carbon-bearing layers, present also within the nanopipes and fullerens; they often break, with obvious formation of a planar structure. Respective alternation of layers may lead to local formation of graphite, which is witnessed in photographies, made using the transmission electron microscopy. Particles, seized by folding, can be trapped in hollows (*a trap trench system*) and start accumulating clusters. The only method so far fixing the newly formed carbon layers is the Raman spectroscopy. It especially concerns the carbon matter, due to various reasons, possessing a small coherent zone. The current paper presents data obtained in the RK MES Institute of Geological Sciences n.-a. K.I. Satpayev, in cooperation with the RK KazNU Institute of Combustion Problems.

Key words: nanoscale, graphene/graphane, graphite.

Introduction. Use of carbon material is associated with large-scale production. One of their sources is natural manifestations. Synthetised substance is programmed for obtaining in a set of designed (pre-calculated) reactions, while a natural substance is formed under unplanned circumstances. At the same time, natural matter exists, i.e., all reactions, leading to its formation and existence under given conditions, are correct.

We find natural carbon matter (geology) in a near-surface zone. That is, in a zone of low temperature and pressure, windy (gases), rainy (atmospheric precipitation), under influence of insulation (sun ray waves). Besides, carbon-containing matter is inseparably integrated with other substances (rocks, minerals, many of which are catalysers not only in respect to carbon matter), under influence of all sorts of nanozones (a nanozone is limited by condition gradients). This predominantly relates to physical and chemical sciences. The realm of formation and existence of nanoparticles is multidisciplinary [1]. Usually, formation energy is sufficient for creating a nanoparticle, and it does not suffice to perform a transit into another state of “large” mass of material. For example, energy produced in tectonic processes is quickly extinguished “to zero”. Natural carbon matter, as a rule, consists of a whole spectrum of probable phases, including those with the film-planar habit. Shall we use all sorts of “new” titles to the natural matter, synthetised and confirmed by some instrumental method, or continue using historically developed old names (graphite and crystalline, fine-crystalline, non-crystalline carbon matter)? How “new substances” look like (not schematically) and relate to “old” definitions?

Nanomineralogy [1] is a multidisciplinary science. Mathematical modelling, physics and chemistry are “reference” disciplines investigating detailed conditions of substance synthesis, properties of obtained materials, suggesting their possible application.

Let us consider graphenes. These theoretically calculated structures, among the first ones, have been developed in the CVD-processes. Recently, increased attention was drawn to them.

In the nature, unidirectional manifestations of graphenes/graphanes are not existent. But manifestations, containing the carbon matter, predominantly with film carbon structures, similar to graphene ones, do exist. In this paper, photographies of transmission electronic microscopy (TEM) are used, and there was no task to discern graphenes from graphanes.

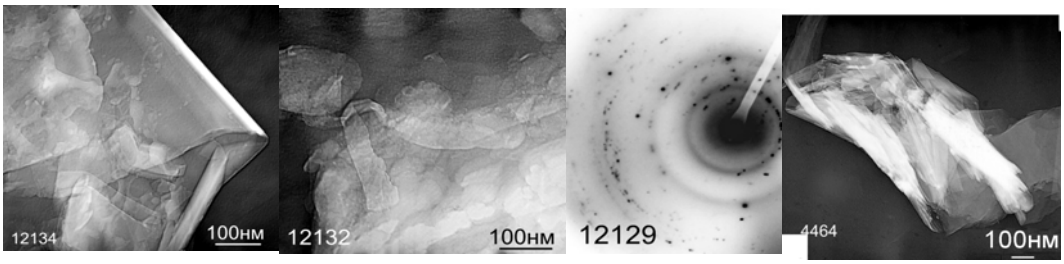
Results and discussion. It follows from the diagramme [2] (figure 1) that grapheme layers can be folded (figure 1a), and the thickened space of the fold can collect admixtures (figure 1b shows fullerene).

a b

Figure 1 – Graphene folding patterns [2]

As it was said earlier, there are great many planar structures in the nature. Let us, basing on microscopic diffraction images, consider only carbon-containing ones: the two- and three-dimensional [3], graphite-like and graphites [4]. The plural form is used because carbon materials of graphites and graphenes/graphanes containing various admixtures are plentiful. Reflexes belonging to carbon matter, as a rule, are widened. A big role is played by scale: often elements composing the matter are of nanoscales. Usual materials are X-ray amorphous. Electrons (TEM, shorter waves) are often capable of detecting non-amorphousness of the X-ray amorphous phases. Specimens for investigations have been prepared uniformly, by one of the dry preparation methods. It excludes any influences of temperature or solvents.

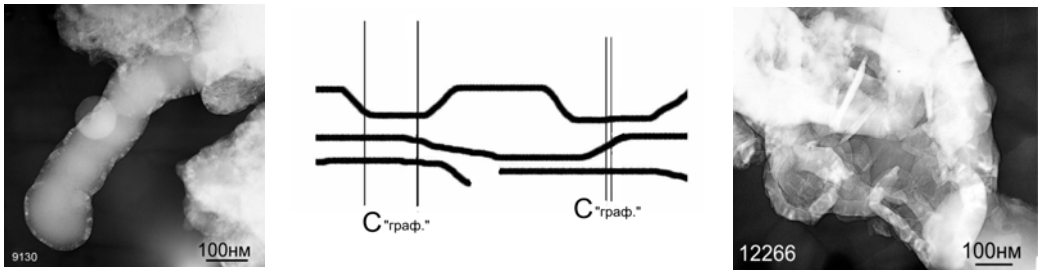
It is seen through microscope that curves of particles have ordinary appearance (figure 2). Folding of *visible* planes (figure 2a) is also not a rare phenomenon. As it was already noticed, carbon substances are present in the nature in unlike phases, for instance (figure 2b), graphites (ribbon particles) and a three-dimensionally ordered matter (the rest of particles' mass). Electrogrammes show them as reflexes grinning through graphite material (more strong dotted reflexes) in the background of widened rings (polycrystallines?) of three-dimensional carbon matter (figure 2c). Figure 2d illustrates a particle (natural too), consisting of "folded" film layers. Its micro-diffraction image relates to graphite.



a b c d

Figure 2 – Morphological images of natural film structure formations:
a, b – the Saryarka field; d – the Nigozero field (Karelia)

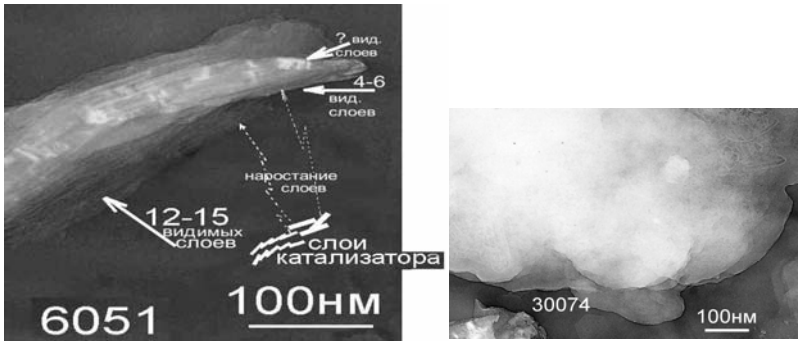
In the figure 3a, a joint existence of graphenes/graphanes and mass has been fixed in a synthetised particle; part of the matter inside the pipe, possibly, is catalytic material for carbon (synthetised matter). Generally, the structure of this tubular formation (figure 3a) is not amorphized. In curves (figure 1b), local graphite gets packed (figure 3b) whih has been described in the work [5]. This matter's micro-diffraction image reveals reflexes of graphites, analogous to those one shown in the figure 2b, in the background of amorphous (structureless) substance. Separating in natural conditions from the central (catalytic) part, the round graphite capsule forms an independent particle, shown in the figure 3c. Its micro-diffraction image corresponds to graphite.



a b c

Figure 3 – a, c – morphology of particles (outside view); b - the diagramme of (possible) formation of local "graphite" packing; c - curved planes of local graphite packing; a - Synthetised particle; c - the Siyakezen field

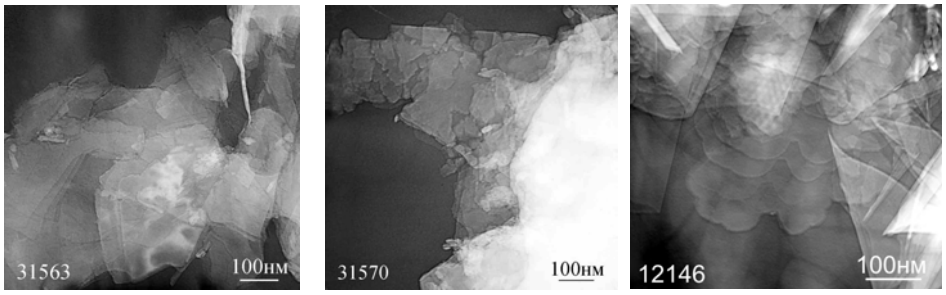
Often encountered are lamellar structures with linear or curved contours of such a locally formed “graphite”. Does it follow that graphites are created locally from graphenes/graphanes? Then, graphene/graphane could be an independent mineral type. It is highly probable that its films have been fixed in carbon compounds (figure 4). Figure 4a shows visible (TEM) layers of basically non-graphite carbon matter. Graphenes/graphanes, as a template, form the first layer, which gradually accumulates carbon mass (figure 4b). This phenomenon is observed both in synthetised and natural formations.



a b

Figure 4 – Graphene layers: a - commercial, b - Koksu

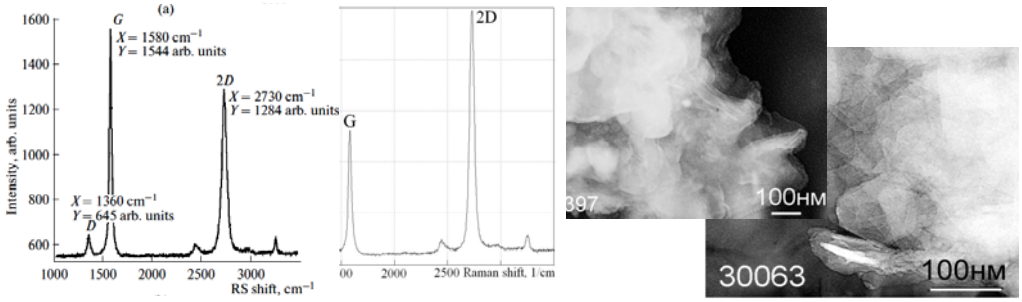
Carbon planar structures (films) can have different scales (figure 5), and this fact may explain the D-peaks discrepancy in the Raman-spectroscopy (figure 6a). Layers of the plain “large” carbon films (up to several nanometers) are shown in figure 5a, small films (first dozens of nanometers) in figure 5b, and a curve carbon layered film packing in figure 5c.



a b c

Figure 5 –Different-scaled natural film particles (the Balta-terek field)

When interconnecting the gauges, it would obviously be possible to tell, what layer thickness and what layer order (in sequence, figure 5) of the Raman-spectra will be obtained (figure 6a). Layers of natural matter would be possible to identify from the relationship between piques I_D/I_G and their relative displacement.



a b c

Figure 6 – The Raman spectra of multilayered (of various discrepancy?) graphenes – a, two-layered particles of natural formation (the Shubarkul field) – b, the trap trench (the Tekeli field) – c

Discrepancy can be connected to quantity of “large and small” surfaces, as well as to presence of various bonds on their endings. TEM is not clear about film thickness. A visible thickness evidently is not atomic. Probably, natural formations contain layers, consisting minimum of two “carbon meshes” (figure 6b). The grapheme film is not a graphene’s layer made only of C-atoms. Rock transformation (squeezing) results in breaking the curved film-lamellar layers, obviously followed by formation of a planar structure (figure 2, 5) and possible local formation of graphite. Particles seized during the folding, also according to the pattern shown in fig. 1b, are singled-out from the trap trench system (figure 6c) for individual development.

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ГРАФЕН ЖӘНЕ ТАБИҒИ БІЛІМ

Аннотация. Жақсы танымал факт-бұл металл фазалардың көп саны Ультрадисперсті күйде. Жалпы құрамы аз өндірілетін фазалар алып отырған елеулі алаңға себілген. Бұл Кенді типке Қазақстанның ірі кен орындары жатады.

Заттың біртектілігі, ағатын процестердің сатылығы табиғи объектілерді зерттеуді бірнеше рет қиындатады. Қатты табиғи көміртекті заттарды "эталондық" заттарға зерттеу кезінде біз берілген термодинамикалық жағдайларда химиялық реакциялардың қатаң ережелері бойынша өтетін химиялық процестердің әр түрлерінде синтезделген көміртекті заттарды таңдап алдық. Табиғи көміртекті зат, әдетте, пленкалы-пластиналы габитус бар мүмкін фазалардың тұтас спектрінен тұрады. Жыныстардың трансформациясы нәтижесінде құрамында көміртекті иілген пленкалы-пластиналы қабаттар, оның ішінде нанотүбектер мен фуллерен қабырғаларында бар, жиі сынады, және анық жазықтық құрылым пайда болады. Қабаттардың тиісті кезектесуі кезінде жергілікті графит қалыптасуы мүмкін. Растау үшін жарық беретін электрондық микроскопиямен алынған фотосуреттер келтіріледі. Бүктелген кезде басып алынған бөлшектер тереңдете - "науалар - арықтар" жүйесінде бөлініп, содан кейін жиналу пайда болуы мүмкін. Түзілетін көміртекті қабаттарды бекітетін жалғыз әдіс Раман-спектроскопия болып қалады. Әсіресе, бұл көміртекті заттарға қатысты, әртүрлі себептермен когенеренттіліктің шағын аймағы бар. Бұл мақалада ҚР БҒМ Қ. И. Сәтпаевтың Геология ғылымдары институтында алынған және ҚР ҚазҰУ-дың Жану проблемалары институтымен достастықта алынған мәліметтер келтіріледі.

Түйін сөздер: наноразмеры, графен/графан, графит.

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ГРАФЕН И ПРИРОДНЫЕ ОБРАЗОВАНИЯ

Аннотация. Хорошо известным фактом является то, что большое количество металлических фаз находятся в ультрадисперсном состоянии. Добываемые фазы с малым валовым содержанием рассеяны на значительной занимаемой площади. К этому рудоносному типу относятся крупные месторождения Казахстана.

Неоднородность вещества, стадийность протекающих процессов многократно усложняют исследования природных объектов. При исследовании твердого природного углеродистого вещества за «эталонные» вещества нами выбраны углеродистые вещества, синтезированные в различных видах химических процессов, протекающих по строгим правилам химических реакций в задаваемых термодинамических условиях. Природное углеродистое вещество, как правило, состоит из целого спектра возможных фаз, часто имеющих пленочно-пластинчатый габитус. В результате трансформации пород изогнутые углеродсодержащие пленочно-пластинчатые слои, имеющиеся, в том числе, в стенках нанотрубок и фуллеренов, часто ломаются, и, очевидно, образуется плоскостная структура. При соответствующем чередовании слоев локально может сформироваться графит. Для подтверждения приводятся фотографии, полученные просвечивающей электронной микроскопией. Частицы, захваченные при сворачивании, могут выделяться в углублениях - в системе «желобков - арычков» и, затем, образовывать скопления. Единственным способом, фиксирующим образующиеся углеродные слои, остается пока Раман-спектроскопия. Особенно это касается углеродистых веществ, по разным причинам обладающих малой зоной когерентности. В этой статье приводятся данные, полученные в институте геологических наук ми К.И. Сатпаева МОН РК и полученные в содружестве с Институтом проблем горения КазНУ РК.

Ключевые слова: наноразмеры, графен/графан, графит.

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REFERENCES

[1] Nanomineralogiya. Ul'tra- i mikrodispersnoye sostoyaniye mineral'nogo veshchestva / Pod red. N.P.Yushkina, A.M.Askhabova, V.I. Rakina. SPb.: Nauka, 2005. 581 p. (in Rus.).

[2] Kwanpyo Kim, Zonghoon Lee, Brad D. Malone, Kevin T. Chan, Benjamín Alemán, William Regan, Will Gannett, M. F. Crommie, Marvin L. Cohen, A. Zettl. Multiply folded grapheme // Phys. Rev. B 83, 245433. Published 27 June **2011** (in Eng.).

[3] Shabanova T.A. Skhema obrazovaniya morfostruktur chastits razlichnogo poryadka (na primere uglerodistykh chastits) // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2010. N 2(269). P. 102-113 (in Rus.).

[4] Mansurov Z.A., Shabanova T.A. Sintez i tekhnologii nanostrukturirovannykh materialov. Almaty: KazNU im. al'-Farabi, 2008. 196 p. (in Rus.).

[5] Shabanova T.A., Glagolev V.A. Fatcheva A.V. Graphite from graphane/graphene layers // Izvestiya NAN RK. Ser. geologii i tekhnicheskikh nauk. 2017. N 5. P 17-20 (in Eng.). https://doi.org/10.32014/2018.2518-170X.1

[6] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[7] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[8] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[9] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[10] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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RESEARCHES OF HYDRODYNAMICS OF INFILTRATION AND COLMATATIONS PROCESSES IN BASINS OF DAILY REGULATION UNDER ARTIFICIAL REPLACEMENT OF GROUND WATER RESERVES

Abstract. The article presents the organization, methods and results of field studies of the water-physical properties of rocks of top sediments in the foundations of infiltration basins, as well as an assessment of their influence on clogging processes. Studies were conducted on a physical model of the mini-pool with water infrastructure and captained structures on the real object and the real conditions of Southeast Kazakhstan. At the same time, the natural conditions of water seepage to the full saturation of the tested power of the rocks of cover sediments were simulated taking into account the spreading of the infiltration flow at the close occurrence of the groundwater level. The obtained full-scale characteristics can be recommended and accepted as the calculated indicators both at the stage of feasibility study and detailed design of the WIP systems without additional labor-intensive and costly survey and research works.

Keywords: artificial replenishment of groundwater reserves, infiltration pool, physical model, pit, volume humidity, maximum molecular moisture capacity, pumping, colmatation.

In the study of the processes of artificial replenishment of groundwater (hereinafter IVZPV), a detailed description of the water-physical, hydrodynamic and filtration properties of cover sediments and upper layers of water-bearing rocks of the aquifer plays a very important and decisive role, especially in the design of open infiltration facilities.

On the territory of South-East Kazakhstan for replenishing the groundwater reserves of the aquifer first from the surface of the earth with low thickness of covering low-permeable sediments, infiltration structures of open-type artificial replenishment systems are most effective [1]. In our case, it may be the most expedient if there is a large regulating capacity in the aquifer.

Performance prediction of such pools may be provided by analogy with the structures of the existing systems of artificial recharge or calculations.

The first method requires the use of long-term data on the operated installation, similar to the factors affecting the value of the performance of the pool with the newly designed. This way can be the most rational only when the newly designed installation is located in the area of the operating system or the extension of the already operated system is projected [2].

In the conditions of South-East Kazakhstan, where there are no built and operated systems of the ERW, the only and acceptable can be the use of the calculation method, for which it is necessary to have data on the composition and permeability of the soils of the base of infiltration basins and the specified mode of their operation [3].

For this purpose, a mini - basin system was constructed with the infrastructure of water intakes and captive structures, imitating the IVZPV system that is optimal for this region in miniature. It carried out a full range of field work in engineering geology and soil mechanics with the drilling of holes and the

sampling of rocks of the aeration zone, as well as hydrological and laboratory studies of surface water as a source of replenishment of operational reserves.

In this work, the following main and defining criteria were used:

- the presence of a potential consumer of accumulated water in the areas of IVPP. Such a consumer is rural settlements with the number from 500 and taking into account the prospect of growth up to 2000 inhabitants. These are primarily those in which residents use either imported water or existing surface sources for drinking water supply do not meet sanitary and epidemiological requirements;
- the presence of water-bearing layers (horizons) with sufficient potential for making the appropriate volume of accumulated groundwater reserves, the required quality and quantity;
- the possibility of using the selected section of the IPPW as a model for the dissemination of the data to similar areas for further implementation and use of research results;
- the possibility of organizing experimental work on the site;
- cost and other technical and economic indicators.

As a result, as the most acceptable alternative object of scientific research processes USPV elected land located on the territory adjacent to the village Ishitobi, a potential consumer of water due to ground-water artificial replenishment of their stocks[4].

The location of the research site on the territory of the Republic of Kazakhstan in Almaty region is shown in figure 1.

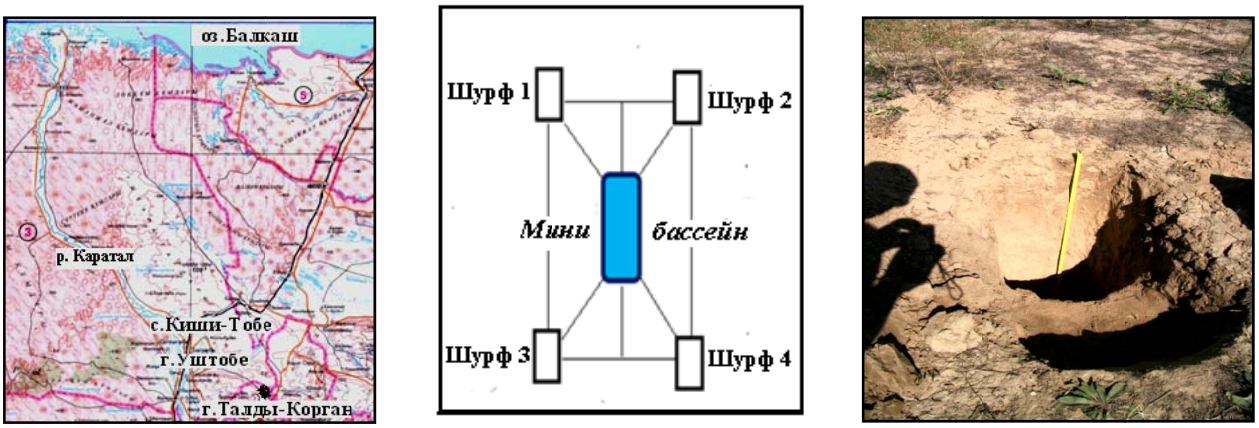

Figure 1 – Scheme of location and general view of made bore pits

Organization of the research area. For the study of water-physical, hydrodynamic and filtration properties along the perimeter in the corners of the conditional envelope of the projected infiltration basin, 4 holes were drilled.

The studies were carried out separately for each opened genetic layer of alluvial-proluvial cover sediments and the upper section of water-bearing rocks of the aquifer.

In the center of the experimental site was passed and equipped with a pit, simulating on a reduced scale projected infiltration pool of daily regulation with the following parameters: Depth - 4,0 m with natural slopes and the size of the top - 2x5 m.

Methods of conducting experimental studies. Studies of the lithological composition and characteristics of the water-physical properties of rocks of top sediments in the grounds of infiltration basins, as well as the assessment of their influence on clogging processes are an integral part of both the feasibility study and the detailed design of the IVZPV systems [5].

Volumetric weight, natural moisture (weight), maximum molecular moisture capacity and other water-physical and filtration properties of rocks were determined using the Litvinov field laboratory (PPL-9).

To determine the granulometric composition of fine gravelly and grainy sandy soils, as well as coarse-grained part of silty - clay soils, the sieve method was used [6] - one of the main in the practice of soil research, which occupies an intermediate position between direct and indirect methods and is widely used in practice independently or in combination with other methods. To separate the soil into fractions by the sieve method without washing with water, sieves with holes with a diameter of 10; 5; 2; 1; 0.5 mm;

with washing with water - sieve with hole size 10; 5; 2; 1; 0.5; 0.25; 0.1 mm. Sieve method with water washing was used to determine the granulometric composition of fine and silty Sands.

To determine the content in the soil of particles with a diameter less than 0.1 mm, an areometric method was used, based on the sequential determination of the density of the soil suspension at certain intervals using a hydrometer. The results of the determinations were calculated diameter and number of particles to be determined.

To determine the granulometric composition of clay soils, a pipetting method was used in combination with a sieve. This method is based on the separation of soil particles by the speed of their fall in calm water. At certain time intervals, samples were taken from a suspension of soil from different depths with a pipette, which were then dried and weighed.

For sands with the inclusion of pebbles, experimental filling was carried out according to the method of A.K Boldyrev. The Boldyrev method is based on the assumption that the pressure gradient in the conditions of the described solution of the problem is close to one (J=1). It should be noted that the results of experiments to determine the filtration coefficient by this method are, as a rule, approximate, depending on the size of the hole section and the duration of the experiment.

The filtration coefficient was determined using the method of pumping water from wells in the experimental area, for which we used the wells of the regime network of RSU Zonal Hydrogeological Reclamation Center of the Ministry of Agriculture of the Republic of Kazakhstan [7]. - № № 153,261 as central and № № 127, 129, 152, 10 (figure 2) as observation wells. The latter were needed to observe changes in the water level at some distance from the Central production during pumping.

Figure 2 – Pictures of central and observation wells No. 261, 10

If the pump capacity (or, what is the same, q flow rate) is constant, then the degree of water level decrease in generation at a constant aquifer power and all other equal conditions depends on the value of the rock filtration coefficient [8].

The smaller the coefficient k, the greater the reduction can be achieved with a certain pump capacity. This dependence is quite natural.

Consequently, it is possible to determine the water permeability of the rock by determining its filtration coefficient k by experimentally determining the dependence of the decrease s of water in the hydrogeological development on a particular flow rate q during pumping (figure 3).

To carry out studies to determine the permeability and volume humidity of cover deposits filling each of the passed pits with water from the river Karatal was carried out from a $2m^3$ volumetric tank equipped with a float system and a flow meter, and constantly replenished with a car-water carrier with a tank capacity of 8 m^3.

To obtain a reliable characteristic of water-physical, water-chemical, hydrodynamic and filtration properties of rocks in the aeration zone, studies were carried out separately for each genetic horizon of the cover deposits at full capacity. At the same time, all existing methods, devices and equipment were previously analyzed, used for these purposes [8, 12].

To create a model of the process of water infiltration from the pool in the zone of incomplete saturation, field studies were conducted by filling the prepared physical model with water-mini-pool with an initial water column of 200 cm and its subsequent operation [9].

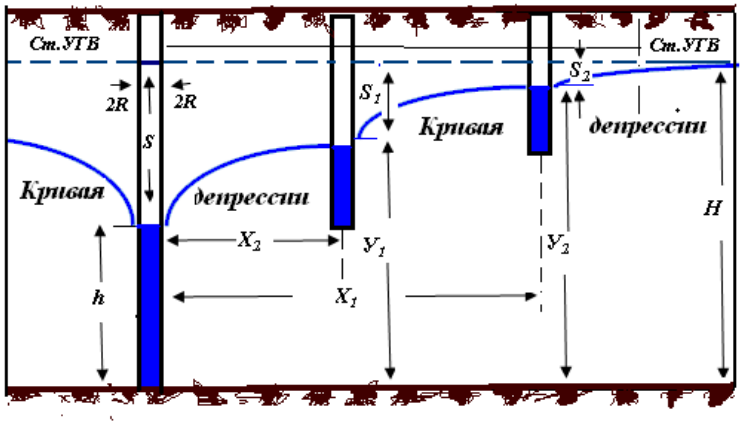

Figure 3 – Filtration coefficient calculation model in the field when dewatering well

Observations were carried out for 78 hours with the following intervals of water flow measurements and the value of water column decrease in the pool per unit of time: during the first 6 hours - after 1 hour, later during the day after 2 hours - and then until the end of the experiment - every 4 hours. At the same time, interval sampling of a water-saturated soil with undisturbed structure was carried out to determine the bulk moisture.

Sampling for the measurement of volumetric humidity was made by layers located at depths: 10, 20, 60, 75 и 90 cm from the bottom of the infiltration mini-pool. Moisture samples were taken immediately after the opening of the next layer to avoid loss of moisture[10].

As a result, to obtain the necessary parameters characterizing these properties when conducting research, a unified approach was chosen, in which a metal frame with a height of 20 cm of rectangular shape with dimensions that follow the dimensions of the slopes of the pit, which was crushed to a depth of 5 cm, was used as a buzzer. In this case, the natural conditions of water infiltration were simulated until complete saturation of the tested thickness of the sedimentary rocks took into account all factors, such as the spreading of the infiltration flow, trapped air, water temperature, close groundwater level, etc. [11, 13].

Field studies of the processes of soaking the base of the mini pool were carried out by measuring the magnitude of the dirt capacity or turbidity of the river water pumped into the infiltration mini-pool. Studies of clogging were carried out simultaneously with the implementation of the experience in studying the permeability, i.e. within 78 hours. A device was used - Turb 355 T/IR Mutnomer, as well as a photometric method of comparing samples of the test water with standard suspensions.

Measuring the turbidity of the river water and the estimation of errors of measurements were performed with the use of latest edition RD 52.08.104-2002 "water Turbidity. Methods of measurement ", developed by the State Institution" State Hydrological Institute "Roshydromet, authors: D.A. Konovalov, N.N. Bobrovitskaya, K.M. Zubkova, L.G. Tkacheva, M.E. Vychezhzhanina. Certified by GU GGI, certificate No. 03-2000 of 11/15/2000.

The portable turbometer works in a wide range from 0 to 1000 FTU (NTU), for greater accuracy, the measuring range is divided into two sub-ranges: from 0 to 50 NTU with a resolution of 0.01 FTU and from 50 to 1000 FTU with a resolution of 1 FTU.

Conversion to mg/l depends on the material and varies greatly, from 1 NTU = 0.13 mg/liter (silica in the form of diatomite) to 1 mg/l (kaolin) [11].

In this regard, the performed calibration of the instrument recommends the use of Russian GOST 3351-74, which establishes the ratio of 1 EM / liter = 0.58 mg / liter for kaolin.

It should be noted that the Mutnomer Turb 350 IR WTW with kaolin suspension and calibration was used for the first time as a scientific experiment to quickly obtain instantaneous turbidity values.

Results of experimental studies. In order to verify the obtained results on the permeability of those rocks, the coefficients of which were determined according to the data of loading, calculations were carried out using empirical formula of Hazen. From which it follows that the greatest difference between the calculated filtration coefficients, determined as a result of the pilot filling, in sandy, well filtering rocks reaches -20.7% and the smallest in sandy beds -1.8%.

The coefficient of water loss (in fractions of a unit) was calculated by the formula P.A. Belinsky according to the values of the filtration coefficient, determined according to the data of pilot fillings.

The coefficient of water loss (in fractions of a unit) was calculated by the formula P.A. Belinsky according to the values of the filtration coefficient, determined according to the data of pilot fillings.

Table 1

Rock names	Water loss coefficient (in fractions of a unit)
Pebble gravel with sandy aggregate	0.171
Medium-grained sand	0.097
Fine-grained sand	0.072
Sandy bean	0.068
Loam	0.078
Loam heavy	0.067
Loam light	0.081

From the lithological composition of rocks depends not only the value of the coefficient of water yield, but also the height of the capillary rise.

Table 2

Rock names	Capillary lift height
Fine-grained sand	0,15-0,25
Clay sand	1.0
Sandy bean	1,05-1,60
Heavy loam	1,35-2,50
Loam light	2,50-3,35

The granulometric composition of the rocks, depending on their genetic connection, is given in the table below the corresponding percentage of fractions.

Table 3 – Grain composition of rocks of covering quaternary deposits

Lithological composition of rocks	Granulometric composition (%) of fractions						
	7,0-5,0	5,0-2,0	2,0-1,0	1,0-0,5	0,5-0,05	0,05-0,005	Less than 0.005
Gravel sand	–	15.2	21.7	–	34.4	14.8	14.8
Coarse sand	9.5	5.3	21.1	1.7	29.9	1.6	0.8
Medium-grained sand	-	43.0	43.0	0.1	5.6	4.9	3.4
Fine-grained sand	–	–	–	–	97.1	0.8	2.1
Sandy loam	–	–	–	–	45.1	33.6	21.6
Sandy loam	–	–	–	–	6.1	51.2	42.7
Clay loam	–	–	–	–	43.6	36.3	20.1

The results of experimental studies to determine the permeability and volume moisture of top sediments with a brief explanation and conclusions are presented in figures 4–7.

Figure 4 shows the constructed diagram of the dynamics of changes in the flow rate of the filtered water to the zone of incomplete saturation and depth of wetting for different stages of saturation of the upper lithological layer of cover sandy loams in pit A-1. The research interval is 100-140 cm. The experiment lasted 26 hours under the given volume of water 1,147 m^3 the magnitude of the drenching 400 mm. Sustained water flow came after 20 hours from the start of the experiment; relatively stable infiltration after 6 hours. Soil density-1.32 g/cm^3, the initial volume humidity-36.7 % of the field capacity and volume or 0.22; at full saturation-73.1% or 0.44 at full capacity. The porosity is 0.6. The difference is due to the presence of trapped air in the pores of the soil [12].

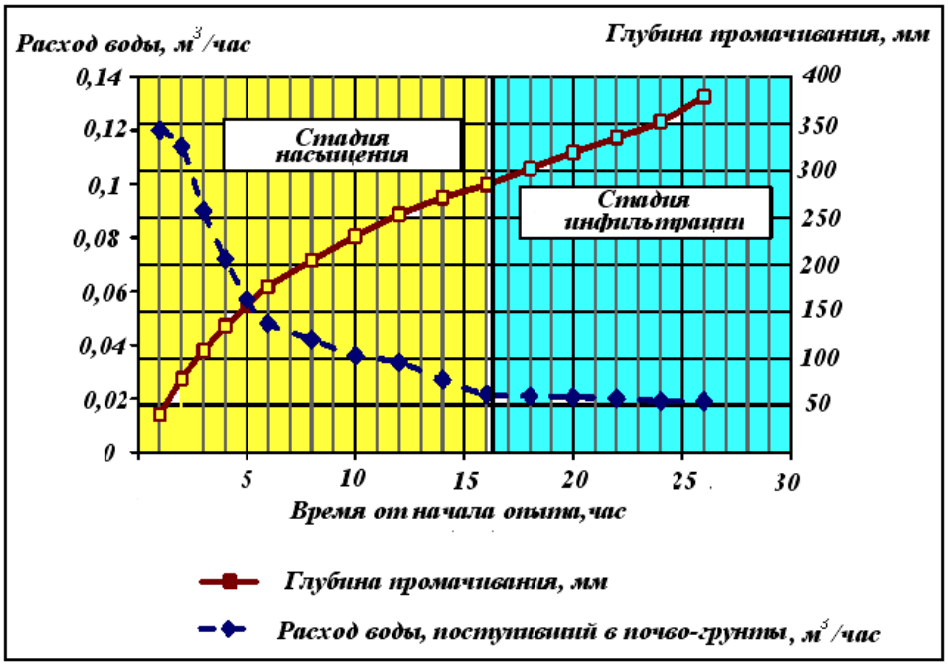

Figure 4 – Changes in filtrated water rate to the zone of subsaturation and depth of wetting for different saturation stages of cover sandy loams. Bore pit A-1 characterizing the upper lithological layer in the section of the subsaturation zone at the pilot site of AGWSP. The weighted average filtration coefficient was 0.3 m/day

The following lithological layer of sediments of the unsaturated zone at the experimental site USPV, research has been carried out in pit B-2, is light loam, grey, medium density summation (figure 5). Research interval-140-200 cm. The experiment lasted 60 hours under the given volume of water 1,240 m^3 the magnitude of the drenching 600 mm. Sustained flow of water came after 40 hours from the start of the experiment; relatively stable infiltration after 16 hours. The density of the soil is 1.29 g/cm^3, the initial volume humidity of sandy loams is 32.5% of the field capacity and volume, or 0.23; at full saturation, 80.87% or 0.57 at full water capacity. The sediment porosity is 0.7 [14].

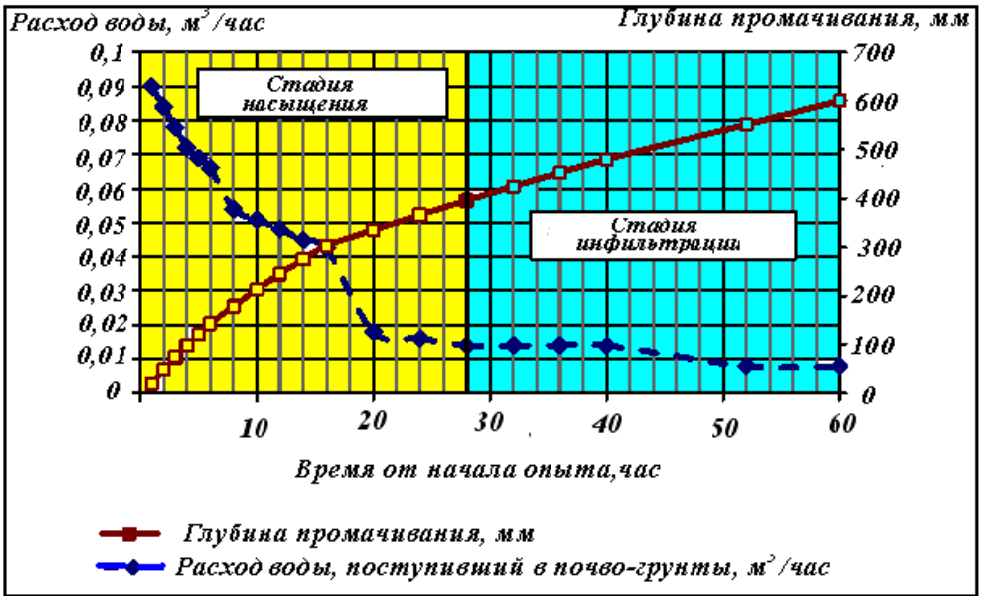

Figure 5 – Changes in filtrated water rate to the zone of subsaturation and depth of wetting for different saturation stages of loam soil. Bore pit B-2 characterizing the second lithological layer in the section of the subsaturation zone at the pilot site of AGWSP

Figure 6 shows the dynamics of changes in the flow rate of filtered water to the zone of incomplete saturation and depth of wetting for various stages of sandy loam saturation in the B-3 hole, characterizing the third lithological layer in the section of the incomplete saturation zone in the experimental section of the IVZPV. In the B-3 pit, studies were conducted on water-physical and filtration properties f surface sediments represented by light gray, fine sand, mica sandy loam in the range of 230-300 cm. The experience lasted for 85 hours under the given volume of water 1,384 m^3 the magnitude of the drenching 700 mm.

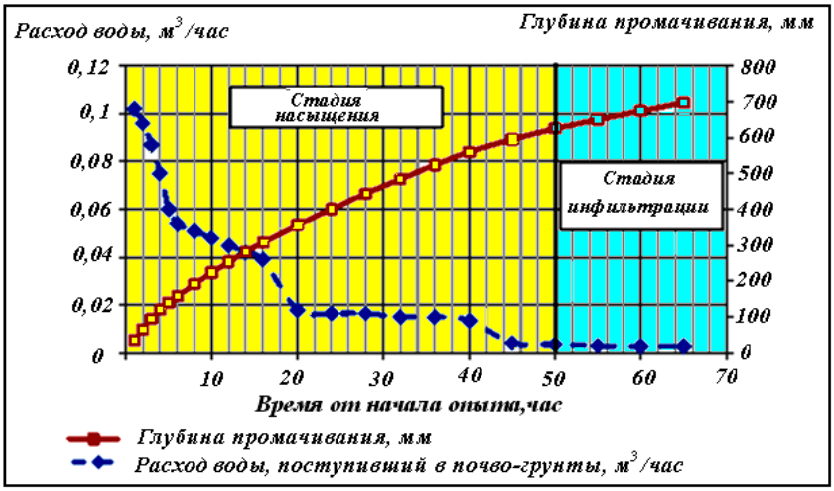

Figure 6 – Changes in filtrated water rate to the zone of subsaturation and depth of wetting for different saturation stages of sandy loam. The bore pit V3 characterizing the third lithological layer in the section of the subsaturation zone at the pilot site of AGWSP

A steady transition from full saturation to infiltration occurred after 75 hours from the start of the experiment; relatively stable infiltration after 8 hours. The density of the soil is 1.39 g/cm^3, the initial volume humidity is 36.7% of the field capacity and volume, or 0.22; at full saturation - 91.38% or 0.55, the porosity of the soil is equal to 0.60. The weighted average filtration coefficient was 0.56 m/day.

The fourth lithological layer in the section of the incomplete saturation zone in the experimental area of the IVZPV, represented by fine-grained gray sand, mica was tested in the G-4 pit in the interval of 310-420 cm (figure 7), from the mark of 390 cm aquifer. The duration of the experiment was 95 hours with a supplied volume of water of 0.971 m^3. Sustained flow of water came after 82 hours from the start of

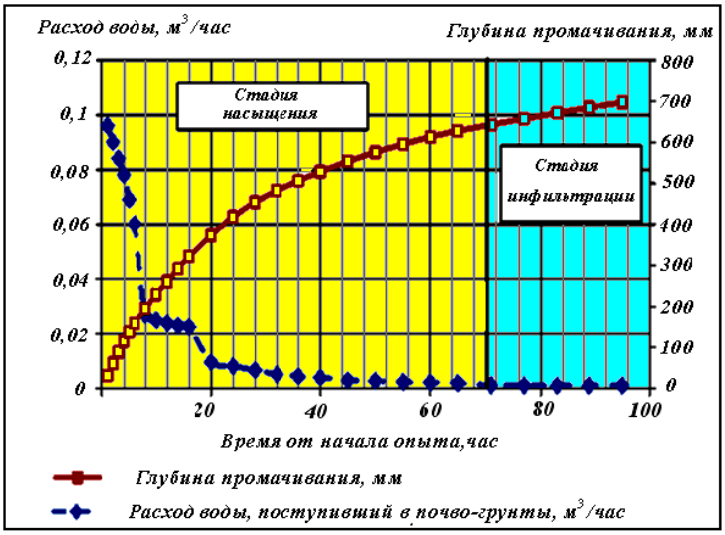

Figure 7 – Changes in filtrated water rate to the zone of subsaturation and depth of wetting for different saturation stages of finely grained loamy sand. The bore pit G-4 characterizing the fourth lithological layer in the section of the subsaturation zone at the pilot site of AGWSP

the experiment; relatively stable infiltration after 8 hours. The density of the soil is 1.34 g/cm^3, the initial volume humidity is 56.7% of the field capacity and volume, or 0.31; at full saturation, 52.1% or 0.53. The porosity is 0.55. The weighted average estimated filtration coefficient was 2.8 m/day at the beginning of the research and 3.4 m/day with full saturation.

To assess the dynamics of the infiltration process through the zone of incomplete saturation to groundwater levels at the experimental site, the following parameters were obtained:

- the initial profile of volumetric humidity (before the pool is flooded);
- the value of the height of the water column in the pool above its bottom and its change in time;
- the value of the total volume of water applied for infiltration and the time of infiltration (from beginning to completion);
- the depth of soaking at the end of the experience;
- profile of volume humidity at the end of the experiment and intermediate time profile of volume humidity.

The resulting material is the constructed profiles and chronoisoplets of one-dimensional volumetric moisture of the cover soils underlying the aquifer of modern and Upper Quaternary alluvial-proluvial undifferentiated sediments with natural composition in conditions of insufficient and complete saturation in the mini-pool in the experimental experimental section of the IVRIZV deposits presented in the figure below.

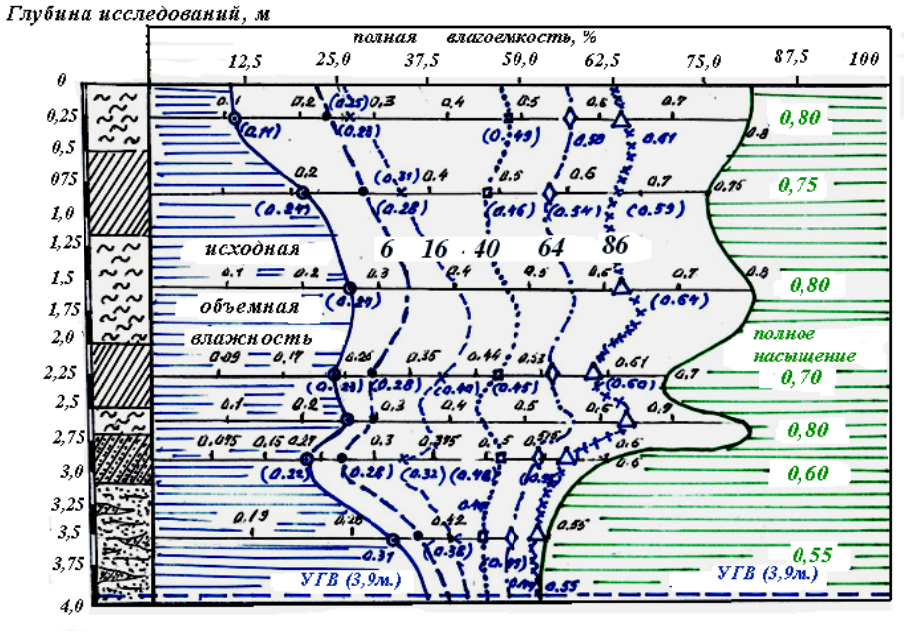

Figure 8 – Profiles and chronoisopleths of one-dimension volume humidity of cover grounds underlying the water bed of modern and upper quarternary alluvial-proluvial poorly defined formations in the context of natural stratification under conditions of insufficient and full saturation in the mini basin at the experimental area of AGWSP - Chronoisopleths of volume humidity,numbers – observation interval in hours . - loam soil - sandy loam - fine sand with sandy loams lenses – loam

– Chronoisoplets of volume humidity, numbers - the period of observations in hours

- loam - sandy loam - fine-grained sand with loam lenses - clay

To confirm the normal functioning of the applied device Motomura Turb 350 IR, WTW and the suspension of kaolin and performed calibration,was carried out additional measurements of optical density of the suspension on a spectrophotometer and the concentration of kaolin in 0,5; 1,0; 1,5; 2,0; 3,0; 4,0; 5,0 mg/l. In each standard solution, the analytical signal was measured by a spectrophotometer at a wavelength of 530 nm, which was used in this type of analysis.

Next, measurements were made in the analyzed solution, which should know the concentration of the substance to be determined. Having obtained the value of the analytical signal, with the help of a calibration graph, a concentration was found that corresponds to this signal. According to the results of measurements of the optical density of standard working suspensions, a calibration graph of the dependence of the optical density on turbidity was constructed.

As is clearly seen in the figure, the calibration graph is expressed as a straight line coming from almost zero, which gives us grounds for asserting that the results of measurements of the turbidity of river water are quite reliable, verified by modern spectrophotometry methods and comparable to traditional gravitational weights with high correlation coefficient.

Table 4 – Results of river water turbidity determination at the site of field studies of AGWSP

Period and duration research			Water volume per unit of time on saturation of the studied layer, m^3	The value of the water layer in the unit of time, mm	Height of the water column in the mini-pool, mm	Turbidity, mg/dm^3
Research date	Research interval, hour	The duration of research, hour				
10.08	1	1	0.440	110	2000	35
	1	2	0.42	105	1890	36
	1	3	0.38	96	1785	37
	1	4	0.36	90	1689	38
	1	5	0.35	87	1602	37
	1	6	0.32	80	1522	36
		6	0.183	568	1522	37
	2	8	0.60	150	1372	35
	2	10	0.576	144	1228	35
	2	12	0.560	140	1088	35
	2	14	0.544	136	952	35
	2	16	0.512	128	824	35
	2	18	0.480	120	704	34
	2	20	0.40	100	604	34
	2	22	0.32	80	524	34
	2	24	0.24	60	464	34
11.08	2	26	0.192	48	416	34
	2	28	0.144	36	380	32
	2	30	0.128	32	348	31
		30	4.696	1174	348	30
	4	34	0.216	54	294	29
	4	38	0.216	54	240	27
	4	42	0.208	52	188	26
	4	46	0.208	52	136	25
12.08	4	50	0.200	50	86	25
	4	54	0.200	50	36	24
		54	1.248	312	36	24
	4	58	0.1936	48.4	-12.4	24
	4	62	0.1936	48.4	-	23
	4	64	0.1936	48.4	-	22
	4	68	0.192	48.0	-	21
	4	72	0.192	48.0	-	22
	4	76	0.192	48.0	-	21
		78	1.1568	2000	0	22
		78	7.284	2000	0	29

Conclusion. In order to obtain the necessary parameters characterizing these properties, a unified approach was chosen in the course of research, in which the natural conditions of water seepage were simulated to the full saturation of the tested power of the rocks of cover sediments, taking into account the spreading of the infiltration flow at the close occurrence of the groundwater level.

The studies were carried out separately for each opened genetic layer of alluvial-proluvial cover sediments and the upper section of water-bearing rocks of the aquifer.

The specific characteristics obtained are: volumetric weight, natural humidity, the level of molecular moisture capacity and other water-physical and filtration properties of rocks in real conditions of artificial supplementary feeding of groundwater for drinking water supply of the population of the settlement.

The site of experimental studies is composed of heterogeneous in the area of distribution and lithological composition, low-power weakly and waterproof cover deposits, the average density of addition.

Surface water river. Karatal are characterized by a low content of suspended mechanical particles: from 12-15 to 25-30 mg/l in the mid-summer and autumn-winter periods, except for periods of flood runoff, when their turbidity reaches up to 120-150 mg/l.

In the process of conducting pilot studies in the infiltration mini-basin, as the water level in it decreased, natural clarification of water occurred and its turbidity decreased to the minimum values: 20-23 mg/l.

The thickness of the formed clay film at the bottom of the mini pool was only 0.09 mm with a volume of filtered water through a mesh of 7.284 m^3 and so small that it could be concluded that there is no danger to the colmatage of pores of aquiferous rocks of fine-grained sands.

In general, the experimental studies carried out at the Karatal experimental site allowed to evaluate the infiltration processes from the infiltration mini-basin, study the process of clogging and silting of infiltration structures, characterize the water-physical, hydrodynamic and filtration properties of the main lithological differences of the sediments at the site of the proposed construction of the artificial replenishment of the underground waters [15].

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ЖЕР АСТЫ СУЛАРЫНЫҢ РЕЗЕРВУАРЛАРЫН СУРЕТТЕРМЕН АЛМАСТЫРУҒА БАЙЛАНЫСТЫ КҮНДЕЛІКТІ РЕТТЕУДІҢ БАСТАМАЛАРЫНДЫ ИНФИЛЬТРАЦИЯ ЖӘНЕ КОЛЬМОТАЦИЯ ПРОЦЕСТЕРІНІҢ ГИДРОДИНАМИКАСЫ ЗЕРТТЕЛДІ

Аннотация. Мақалада инфильтрациялық бассейндердің негізіндегі жоғарғы шөгінділердің су-физикалық қасиетерінің далалық зерттеулерін ұыймдастыру, әдістері мен нәтижелері, сондай-ақ олардың бітелу процестеріне әсерін бағалау қарастырылған. Зерттеулер шынайы объектіде және Оңтүстік-Шығыс Қазақстанның нақты жағдайында су қабылдайтын инфрақұрылымы мен тұтқыр құрылымдары бар шағын бассейннің физикалық моделі бойынша жүргізілді. Сонымен қатар жер асты суларының деңгейіне жақын болған кезде инфильтрация ағынын таратуды ескере отырып, ашылатын шөгінділердің жыныстарының сыналған қалыңдығын толығымен қаныққанға дейін судың инфильтрациясының табиғи жағдайлары модельденді.

Түйін сөздер: жер асты суларын жасанды толтыру, инфильтрация бассейні, физикалық модель, тесік, көлемдік ылғалдылық, максималды молекулалық ылғалдылық қабілеті, сорғы, бітеу.

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ИССЛЕДОВАНИЯ ГИДРОДИНАМИКИ ПРОЦЕССОВ ИНФИЛЬТРАЦИИ И КОЛЬМАТАЦИИ В БАССЕЙНАХ СУТОЧНОГО РЕГУЛИРОВАНИЯ ПРИ ИСКУССТВЕННОМ ВОСПОЛНЕНИИ ЗАПАСОВ ПОДЗЕМНЫХ ВОД

Аннотация. В статье приводятся организация, методика и результаты проведенных натурных исследований водно-физических свойств пород покровных отложений в основаниях инфильтрационных бассейнов, а также оценка их влияния на процессы кольматации. Исследования проводились на физической модели мини-

бассейна с инфраструктурой водозаборных и каптажных сооружений на реальном объекте и для реальных условий Юго-Восточного Казахстана. При этом были смоделированы естественные условия просачивания воды до полного насыщения испытываемой мощности пород покровных отложений с учетом растекания инфильтрационного потока при близком залегании уровня грунтовых вод. Полученные натурные характеристики могут быть рекомендованы и приняты в качестве расчетных показателей как на стадии технико-экономического обоснования, так и рабочего проектирования систем ИВЗПВ без проведения дополнительных трудоемких и затратных изыскательских и исследовательских работ.

Ключевые слова: искусственное восполнение запасов подземных вод, инфильтрационный бассейн, физическая модель, шурф, объемная влажность, максимальная молекулярная влагоемкость, откачка, кольматация.

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REFERENCES

[1] Antonenko V.N., Mirlas V.M., Kuldeev E.I., Kulagin V.V., Kuldeeva E.M. Development of a method of artificial replenishment of underground water reserves and research of prospects of its use for drinking water supply in South-East Kazakhstan // Report on research work. UDC 551.49626.01. State rubricator of scientific and technical information: 38.61.05. Astana, 2014. P. 12-56.

[2] Burchak T.V. Artificial replenishment of groundwater. Calculation of pools and their systems. Kiev, 1986.

[3] Antonenko V.N., Kuldeev E.I. Investigation of the process of artificial replenishment of groundwater // Mat. intl. conference dedicated to the memory of V. I. Khain. M.: Moscow state University, 2011. P. 105-112.

[4] Myrzakhmetov M.M., Orman A., Garbalau N.M. Technological research on artificial replenishment of underground water city // Shymkent's. Mag. Water and technology. St. Petersburg, 2007. N 2. P. 14-22.

[5] Krainov S.R., Shvets V.M. Hydrogeochemistry. M.: Nedra, 1992. A brief guide to the design of infiltration facilities for artificial replenishment of groundwater for the purpose of drinking water supply. Academy of public utilities Russian Soviet Federal Socialist Republic. M., 1972.

[6] Verigin N.N., Vasilyev S.V., Sarkisyan V.S., Sherzhukov B.S. Hydrodynamic and physico-chemical properties of rocks. M.: Nedra, 1977. 271 p.

[7] Shestakov V.M. Assignment of tests for groundwater inflow near streams. Intelligence and security. M.: Nedra, 1977. N 9. P. 38-44.

[8] Babushkin V.D., Plotnikov I., Chuyko V.M. Methods of studying filtration properties of heterogeneous rocks. M.: Nedra, 1974. 208 p.

[9] Grigoriev V.M. From operating experience of infiltration water intakes. “Proceedings of the VODGEO Institute”. M.: Gosstroyizdat, 1958.

[10] Antonenko V.N. Prospects for groundwater storage in southeastern Kazakhstan // Proceedings of the international conference “Water: resources, quality, monitoring, use and protection of waters”. Almaty, 2008. P. 152-155.

[11] Antonenko V.N., Kuldeev E.I. Features of groundwater storage. Geology in the XXI century // Materials inter. scientific. practice. conf. "Satpayev's reading". Almaty, 2011. P. 35-40.

[12] Jaksmuratov K.M. Hydrogeological conditions of shrinkage and demineralization of groundwater lenses in the south of the Aral Sea region: Candidate of Geological and Mineralogical Sciences. Almaty, 1997. 19 p.

[13] Mukhamedzhanov M.A., Jai Sagin, Kazanbaeva L.M., Rakhmetov I.K. Influence of anthropogenic factors on hydrogeochemical conditions of underground drinking waters of Kazakhstan. Алматы, 2018. https://doi.org/10.32014/2018.2518-170X.1

[14] Mukhamedzhanov M.A., Jai Sagin, Nurgaziyeva A.A. Relation between surface water and groundwater as the factor for formation of groundwater renewable resources on the territory of Kazakhstan. https://doi.org/10.32014/2018.2518-170X.4

[15] Murtazin Y.Z., Miroshnichenko O.L., Trushel L.Y. Methods of making of geoinformational and analytical system of groundwater resources in Kazakhstan. https://doi.org/10.32014/2018.2518-170X.6

[16] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[17] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[18] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[19] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

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PURIFICATION DEGREES OF WASTE WATER UNDER DIFFERENT IRRIGATION REGIMES

Abstract. In the process of irrigation wastewater treatment is as its movement in the horizontal direction, and when leaking from top to bottom on the soil profile.In order to identify the degree of soil purification of wastewater, a complex of lysimetric studies was carried out in the territory of Almaty, Zhambyl and South Kazakhstan regions in various varieties of loamy soils.

Key words: lysimeters, aeration, biological uptake, wastewater, ingredients.

Introduction. Metal lysimeters had a height of 35, 65, 95, 155, 205 cm, and soil monoliths 30, 60, 90, 150, 200 cm. Lysimeters of small height (up to 1.5 m) were filled with monoliths of undisturbed structure, and more than 1.5 m - with soil of natural genetic structure with compaction close to natural.The inner surface of the lysimeters was covered with bitumen in 2 layers, filtered water through the pipe was sent to special containers. The lysimeters were planted with the same crops as for wastewater treatment and the irrigation regime was identical.

Comparison of the data of the chemical composition of the source water and filtration makes it possible to judge the degree of its purification.

The general quantitative and qualitative expression of the processes of absorption and migration of ingredients in waste water introduced into the soil with irrigation water had their regularities [1, 3].

Wastewater treatment occurred mainly in the zone of aeration, where he is actively in the process of nitrification, oxidation of proteins, cation exchange, biological uptake, etc. (table 1).

Sixty centimeter layer of soil, depending on the value of irrigation norms holds up to 100% of suspended solids, from 80 to 91% of nitrogen and from 90 to 99% of phosphorus.

Reducing the degree of purification soil of various ingredients can be found in the weakening at the end of the vegetation consumption of their higher vegetation, reducing the end of the vegetation consumption of their higher vegetation, reducing the microbiological activity of serozems, the relative "saturation" of the filter layer by the substances, changing the cationic composition of the arable horizon as a result of irrigation, meteorological conditions and other factors individually or in combination causing changes in the sorption properties of the soil.

Similar phenomena were observed in the crops of maize for silage in South Kazakhstan region (table 2).

From mineral elements absorption of phosphorus was greater than the absorption of nitrogen.As irrigation rates increase, losses of nitrogen and phosphorus increase (table 3).

The absorption of the upper soil horizons decreases from irrigation to irrigation depending on the frequency of irrigation and water supply rate. Naturally, the greater the rate of water supply, the greater the flow of various organomineral substances. In this regard, the soil is oversaturated in a short period of inter-irrigation period does not have time to be completely exposed to various soil processes.

V.T.Dodolina noted that during the inter-irrigation period, part of the absorbed substances will be used by agricultural crops, and part under the influence of various processes is decomposed into simple compounds.

Table 1 – The degree of absorption of waste water ingredients by different soil layers, % (average loam) (on sugar beet crops)

# irrigation	Irrigation norm, m^3/ha	Layer, cm	Suspended matter	HCO_3	Cl	SO_4	Ca	Mq	Na+K	N	P_2O_5
Option II (irrigation at 60% of the water pressure)											
1	700	0-30	50	40	50	40	40	40	42	60	50
		30-60	50	41	31	32,9	37	55	20	40	30
	Total	0-60	100	81	81	72,9	77	95	62	100	80
4	1100	0-30	50	39	40	50	39	40	45	50	45
		30-60	50	44	18	18	28	40	24	29	25
		60-90	–	7	22	22	19	20	15	1,0	6
	Total	0-90	100	90	80	90	86	100	84	80	76
Option III (irrigation at 70% of the water pressure)											
1	500	0-30	60	51	52	44	31	50	50	58	51
		30-60	40	45	30	45	69	36	38	34	28
	Total	0-60	100	96	82	89	100	86	88	92	79
7	800	0-30	60	40	10	30	24	44	40	49	46
		30-60	40	18	10	30	12	16	10	30	19
		60-90	–	28	50	21	17	36	36	17	25
	Total	0-90	100	86	70	81	53	96	86	96	90
Option IV (irrigation at 80% of the water pressure)											
1	400	0-30	55	49	68	40	27	60	55	63	58
		30-60	45	43	20	51	68	28	39	35	33
	Total	0-60	100	92	88	91	95	88	94	98	91
10	650	0-30	40	30	10	25	10	30	41	40	46
		30-60	50	16	18	14	22	10	6	29	15
		60-90	10	43	55	39	34	60	41	31	31
	Total	0-90	100	89	83	78	66	100	88	100	92

Table 2 – Degrees of wastewater treatment by different soil layers on maize crops for silage (SKR)

Soil layer, cm	Norm of watering, m^3/ha	Ingredients, mg/l					
		HCO_3	Cl	SO_4	Ca	Mq	Na+ K
0-30	700	120,7	19,8	72,6	31,2	11,6	50,4
0-30	900	131,3	21,2	74,3	31,8	12,6	53,4
30-60	700	96,4	11,4	34,3	10,5	6,3	20,5
30-60	900	87,2	10,1	32,6	9,9	6,0	18,7
60-100	700	14,6	6,2	18,9	5,3	2,8	7,2
60-100	900	12,3	5,9	16,2	5,4	2,4	6,6
Source water		235,0	36,51	174,2	77,0	20,4	102,0

Table 3 – Absorption of N, P, K in different soil layers

Performances	In layer, cm	Norms of watering, mm						
		400	500	600	700	800	900	1000
Phosphorus	0-30	61	58	60	50	41	56	50
Nitrogen	0-30	58	51	50	50	46	48	50
Phosphorus	0-90	99	93	92	90	91	79	79
Nitrogen	0-90	91	80	88	86	80	65	70

The longer the inter-irrigation period, the higher the absorbing capacity of the soil, and hence the degree of purification.

Research materials and the above data show that on gray soils with deep groundwater, irrigation with a moisture threshold, 70% water norm provides not only high yields, but also an appropriate degree of soil post-treatment in the root layer.

In Almaty region were laid lysimeters depth of 1.5; 2, 3 meters.

Experimental data showed that at a depth of 1.5 m the filtrate was almost clean, and at a depth of 3.0 no changes in soil moisture were observed.

Therefore, while maintaining the optimal irrigation regime and its observance, wastewater does not affect the depth of more than 3 m [2, 4-7].

Methods. Under conditions of irrigation with wastewater, the following agrotechnical indicator is effective in substantiating the optimal values of irrigation rates and the dose of fertilizers on all types of soil: chemical composition (N, P, K content) of main and by-products; removal of elements of the mineral nutrition of the harvest unit; soil availability with nitrogen, phosphorus, potassium and microelements permissible for plants: use of fertilizers from the soil by field crops depending on the soil type, weather conditions and the level of specified crops; payback of 1 kg N, P, K. Therefore, the correct determination of the irrigation rates and the dose of fertilizers calculated for the programmed level of the crop is one of the most important elements of the entire ecosystem under consideration.

In order to use the technique in question, it is necessary first of all to calculate the "B" removal of the corresponding mineral nutrient elements with a programmed yield. Knowing the level of the yield programmed at this stage (where $Y_0$is the programmable yield of the main product, centners per hectare), and having the ratio of main production and secondary production (Y_n), it is easy to make the removal of nutrients using the ratio:

$$B_0 = Y_0 \cdot C_0 + Y_n \cdot C_n \,, \tag{1}$$

where C_0 – nutrient content per unit of main product (kg/c); C_n – nutrient content per unit of by-product (kg/c); Y_n – by-products of the programmable crop, which is determined by the formula;

$$Y_n = \alpha \cdot Y_0. \tag{2}$$

Here is α – coefficient that takes into account the ratio of the main product to the by - product (for corn – 2.8, perennial grasses – 0, barley – 1.1, winter wheat – 1.4).

The amount of expected receipt of mineral substances with waste water is determined by the formula:

$$N_m = \alpha \cdot M/100;\ P_m = \varphi \cdot M/1000;\ K_n = k \cdot M/1000, \tag{3}$$

where N_m, P_m, K_n – the amount of expected intake of nitrogen, phosphorus and potassium, kg/ha; α, φ, k – content of nitrogen, phosphorus and potassium, mg/l.

Possible removal of the input mineral substances with waste water is determined from the following expressions:

$$N_{yn} = N_m \cdot \alpha_n; \tag{4}$$

$$P_{yn} = P_m \cdot \alpha_\varphi; \tag{5}$$

$$K_{yn} = K_m \cdot \alpha_k, \tag{6}$$

where N_{yn}, P_{yn}, K_{yn} – possible removal of nitrogen, phosphorus and potassium with a yield of incoming mineral substances with waste water (kg/ha); α_n, α_φ, α_k – utilization rate of nitrogen, phosphorus and potassium from wastewater.

The amount of nitrogen, phosphorus and potassium used from the soil is calculated by the formula:

$$N_{yp} = N_p \cdot \alpha_{np}; \tag{7}$$

$$P_{yp} = P_p \cdot \alpha_{\varphi p}; \tag{8}$$

$$K_{yp} = K_p \cdot \alpha_{kp}, \tag{9}$$

where N_{yp}, P_{yp}, K_{yp} – nitrogen, phosphorus and potassium content in soil, kg/100; N_p, P_p, K_p – amount of nitrogen, phosphorus and potassium used by plants from the soil; α_{np}, $\alpha_{\varphi p}$, α_{kp} – utilization rate of nitrogen, phosphorus and potassium from soil.

At the same time, the need for mineral fertilizers should be decided in each case, based on the following definitions:

1. If the amount of nitrogen, phosphorus and potassium used from the soil and wastewater is less than the removal of these nutrients by crop products, i.e.,

$$B_N > N_{yp} + N_{yn}\ ; \tag{10}$$

$$B_p > P_{yp} + P_{yn}; \tag{11}$$

$$B_k > K_{yp} + K_{yn}. \tag{12}$$

Then mineral fertilizers are made from the calculation of compensation of the differences.

2. If the amount of nitrogen, phosphorus and potassium used from the soil and wastewater is greater than or one of them is greater than the removal of these nutrients by the crop production, i.e.,

$$B_N < N_{yp} + N_{yn}\ ; \tag{13}$$

$$B_p < P_{yp} + P_{yn}; \tag{14}$$

$$B_k < K_{yp} + K_{yn}. \tag{15}$$

Then the irrigation rate of crops is determined by the maximum value of the nutrient removal of one of the nutrients and mineral fertilizers are taken out of the calculation of compensation for the deficiency of other nutrients.

Irrigation norm of agricultural crops under irrigation by sewage is calculated by the formula:

$$M_{na} = [B(NPK)i - P(NPK)i] \cdot 100/\alpha_i\ , \tag{16}$$

where M_{na} – irrigation norm of agricultural crops taking into account the fertilizer value of waste water, m^3/ha; $B(NPK)i$ – removal of the 1st nutrient element by agricultural products; $P(NPK)i$ – use of the 2nd nutrient element from the soil; α_i – utilization rate of the 3rd nutrient element from wastewater.

If $M_{na} < M$ then, the necessity of extra amount of water, compensating the deficiency of water consumption of agricultural crops, i.e.:

$$\Delta M = M - M_{na}, \tag{17}$$

where ΔM – additional rate of supply of irrigation water to compensate the water deficit of agricultural crops.

Consequently, one of the main tasks in the use of wastewater for irrigation is to determine the share of irrigation water in the water deficit, providing optimal water-salt and food regime of the soil and high crop yields.

For the participation of irrigation water in the deficit of water consumption of agricultural crops in irrigation with waste ater is determined by the formula:

$$\alpha_c = I - \frac{B(NPK)i - P(NPK)i}{\alpha_i \cdot M} \cdot 100. \tag{18}$$

Thus, the account of nutrients content in waste water provides a normal natural regime of the soil and economical to the introduction of these elements in the form of fertilizers.

Thus, the following should be taken into account when establishing the irrigation regime for wastewater irrigation:

In some (critical) periods of vegetation, crops may be unsatisfactory inflow of wastewater. Additional irrigation from natural water bodies – rivers, reservoirs or groundwater-can be used to replenish this moisture deficit.

The amount of additional water needed to cover the water shortage is found by the formula:

$$M_a = W_w - Q_{ad} \cdot T_k, \quad (19)$$

W_w – the need of the culture in water for the critical period, m^3/ha; Q_{ad} – average daily consumption of wastewater coming from the city, m^3/ha; T_k – the duration of the critical period in days.

In the practice of designing wastewater treatment, such periods are established by comparing the crop irrigation hydraulic module in the crop rotation (q in l/sec per 1 ha) with the wastewater supply hydraulic module determined by the formula:

$$q_1 = \frac{Q_{ad}}{86{,}4 \cdot \omega}, \frac{l}{cek}, \quad (20)$$

where Q_{ad} – average daily waste water consumption, m^3/day; ω – area of simultaneous irrigation, ha.

When establishing irrigation and irrigation standards, it is necessary to take into account the cleaning capacity of the soil.It is known that during irrigation and subsequent movement of waste water on the surface and on the profile of the soil, their intensive purification occurs due to the mechanical, molecular sorption, ion-sorption, chemical and biological absorption capacity of the soil.The effect of soil purification decreases with increasing water supply rates.On loamy soils of the southern zone of Kazakhstan, intensive cleaning occurs at irrigation rates up to 600 mm, and at a rate of 900 mm and more, the soil will not give a cleaning effect.

Results. Each soil is characterized by a certain absorption capacity. The larger it is, the higher the degree of wastewater treatment.For example, loamy soils of Zhambyl, South Kazakhstan and Almaty regions have high absorption capacity. In the meter layer of these soils, on average, 60 to 90% of the elements of mineral nutrition are retained.

As irrigation rates increase, the number of irrigations and the capacity of the soil filter layer decrease will be less pronounced.

By the end of the growing season and subsequent years of irrigation, the absorption capacity of the soil is somewhat reduced. This is due to the fact that the soil with long-term irrigation is oversaturated with substances brought with wastewater and its cleaning ability is gradually reduced.Therefore, it is very important to maintain a balance between the flow of waste water ingredients and their use by plants.

One of the reasons for the "fatigue" of the soil of irrigation fields is the overload of soil with irrigation water both during the growing season and during the non-vegetation period.As a result of the overload in the soil, the processes of transformation of substances can not proceed normally, soil fertility is ensured.

For the correct use of waste water must necessarily take into account the water-holding capacity of the soil. For wastewater treatment, the amount of runoff should be zero. Water supplied in excess of the water-holding capacity of the soil enters the groundwater.

The smaller the irrigation rate and the longer the irrigation time, the greater the difference between the inflow and outflow of wastewater.The irrigation rate should be calculated so that it does not exceed the permissible ultra-precise value of the intensity of infiltration of irrigation water and the permissible depth of the groundwater level.The value of infiltration and groundwater reaches its peak in the spring, during the snowmelt.It is, all other things being equal, on average twice as much as the growing season, when water is expended heavily on evaporation and transpiration by vegetation.Therefore, the annual irrigation rate should be sufficiently consistent with the conditions of underground outflow of groundwater, to ensure the possibility of neutralization and treatment of waste water in the infiltration process, also fully take into account the needs of plants in moisture.In order to reduce winter irrigation norms, it is necessary to organize irrigation of the entire area of irrigation fields.

The basis of the year-round irrigation cycle for wastewater treatment should be the satisfaction of the crop with moisture during the growing season and the accumulation of essential nutrients in the soil during the growing season.

The basis of the irrigation regime should be the creation of a predominant downward current, providing leaching of salts from the upper horizons of the soil.There was no danger of soil alkolining, for which the amount applied with wastewater and in the form of calcium fertilizer was greater than the amount applied with wastewater sodium. Because of this, when calculating the irrigation regime, it is necessary to observe the balance:

a) nutrients from wastewater;

b) moisture;

c) water-soluble salts.

Of the above, the most important is the provision of water to plants, which is crucial in the formation of the basis of the future harvest, especially in the southern regions of the country and the balance of water-soluble salts, which remain in large quantities after treatment facilities.

Irrigation regime of agricultural crops of wastewater treatment should consist of vegetation and non-vegetation irrigation regimes.

The basis of irrigation regime of vegetation irrigation should be based on the same principles as in conventional irrigation.

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ӘРТҮРЛІ СУҒАРУ РЕЖИМІ КЕЗІНДЕГІ ТӨГІНДІ СУЛАРДЫ ТАЗАРТУ ДӘРЕЖЕСІ

Аннотация. Суғару процесі кезінде төгінді суларды тазарту көлденең бағытта, топырақ профилі бойынша жоғарыдан төмен қарай жүреді. Алматы, Жамбыл және Оңтүстік Қазақстан облыстарының аумағында топырақты төгінді сулардан тазарту дәрежесін анықтау мақсатында саздақ топырақтардың әртүрлі сорттарында лизиметрлік зерттеу кешені жүргізілді.

Түйін сөздер: лизиметр, аэрация, биологиялық жұту, төгінді сулар, ингредиенттер.

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СТЕПЕНЬ ОЧИСТКИ СТОЧНЫХ ВОД ПРИ РАЗЛИЧНЫХ РЕЖИМАХ ОРОШЕНИЯ

Аннотация. В процессе полива очистка сточных вод происходит как при ее движении в горизонтальном направлении, так и при протекании сверху вниз по профилю почвы. С целью выявления степени очистки почвы от сточных вод на территории Алматинской, Жамбылской и Южно-Казахстанской областей в различных сортах суглинистых почв был проведен комплекс лизиметрических исследований.

Ключевые слова: лизиметры, аэрация, биологическое поглощение, сточные воды, ингредиенты.

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REFERENCES

[1] Shulz M. Year-round irrigation with wastewater. M.: Kolos, 1965.

[2] Anuarbekov K., Zubairov O., Nusipbekov M. Improving water-salt regime in irrigated agriculture // Life Science Journal. 2014. 11(5). P. 459-464. ISSN 1097-8135.

[3] Kanardov I.P. Use of wastewater for irrigation. Rosselchozizdat, 1977.

[4] Anuarbekov K.K and other. Water-saving technology of irrigation of corn // Journal News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 2, N 428. P. 149-155.

[5] Anuarbekov K.K. and other. Exploitation of wastewater irrigation system (WWIS) // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 6, N 432. P. 129-136. ISSN 2224-5278. https://doi.org/10.32014/2018.2518-170X.43

[6] Anuarbekov K.K., Zubairov O.Z., Nusipbekov M.Z. Influence of the improvement of water-salt regime on the yield // Biosciences Biotechnology Research Asia. April 2015. Vol. 12(1). P. 999-1006.

[7] Alimbayev Y.N., Anuarbekov K.K., Kalybekova E.M., Sagaev A.A., Zhailaubaeva M.M. Improvement of the ecological and meliorative state of the irrigated lands in the lower course of the Syr Darya // International Journal of Pharmacy & Technology. Dec-2016. Vol. 8. Issue 4. P. 27143-27157.

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FORMATION MANAGEMENT IN PARTS PROCESSING REGENERATED BY SURFACING

Abstract. In this paper, we consider the control of the shape formation of the surface and the formation of specified properties, with the restoration of parts by overlaying. As an economically advantageous way of forming the re-welded part by the authors, a method of friction treatment is proposed. A mathematical model of thermal processes in the tool and part has been developed, which makes it possible to calculate temperatures in contacting bodies by calculation and to provide values close to optimal.

It has been experimentally established that the temperature field in the instrument is determined by a number of factors: the operating time, the thermos-physical and physic-mechanical characteristics of the instrumental and processed materials; intensity of heat release, dimensional characteristics of contacting bodies. In modelling, taking into account the schematization, the part is represented as a semispace, along the surface of which a linear thermal source of length B, intensity q_1, moves with speed S_m with boundary conditions of the second kind.

Also shown is a dependency of heating temperature of the disk from the distance to the heat source. It is established that a fairly sharp drop in temperature occurs as the heat source is removed. Relatively high temperatures remain at a distance R <10 mm, after which a sharp decrease is observed.

The maximum value of the instrument's heating temperature during the entire period of resistance did not exceed 90 °C. The average value of the disk heating temperature was 70÷75 °C.

Keywords: overlaying, friction treatment, temperature field, heat source, friction disk, thermal conductivity, thermo-friction cutting.

The relevance of research. Modern machine engineering constantly increases the requirements for the quality of the surface of critical parts, which entails the further development of new approaches and methods for controlling surface shaping processes.

At present, methods for multi-electrode welding and overlaying in protective environments are mainly used for the repair and restoration of engineering parts. The range of parts is quite diverse, starting from the cross-section of cardan shafts, hinges to tooling and stamps.

Methods combined with machining processes in the plastic condition, as well as methods for controlling the composition and structure of the overlayed metal by forming combinations of electrodes and filler materials, allow metal transfer through a concentrated energy flow (arc) during its deposition [1, 2]. Intensification of the above processes is achieved through the use of shock loads, the combination of different methods of processing by concentrated energy flows (CEF), the use of powder and nanomaterials as the main and filler materials. Electro-physical methods of processing are widely used, such as elastic vibrations of sound and ultrasonic frequency ranges, vibration processing, high frequency currents, laser and electron radiations. Despite the offered technologies, significant growth in the quality of the material structure, and therefore the level of the product properties complex, is not achieved due to a constant

change in the parameters of the crystallization process associated with the dynamics of heat input and heat removal from molten metal, changes in the chemical composition of the melt, formed by the electrode material, filler material and the main metal of the product, which passes into the melt. The structure of the seam is formed as a result of a balance between the processes of heat transfer, diffusion, chemical reaction between the alloy components against the background of a rapid transition of the melt from overheating to supercooling. At the same time, the qualitative and quantitative indices of the crystallization process, even if expensive materials and equipment are used, can influence the results of the technological process in very wide redistribution, up to the point of putting the product into flaw. The most effective results can be achieved by using combined technologies, such as sonication, additional thermal effects on the melt during the treatment with concentrated energy flows (CEF), the use of forced shaping processes and combined machining (for example, frictionmachining).

Particular importance in welding and overlayinghas the formation of structure around the seam zone and the weld metal itself in connection with the periodicity of the thermal action on them during heating, cooling and crystallization [2, 3]. In most cases, the periodicity of the main technological effect on the product is compensated for by periodic auxiliary technological influences such as preheating the surface to reduce the temperature gradients in welding and surfacing in the base material, the subsequent heating or cooling in thermostats to reduce the cooling rate, the periodic thermal action on the molten metal in the process of its crystallization, periodic electromagnetic and ultrasonic effects e for the purpose of grinding the structure of the weld metal, using the vibrations of the welded article; impulse supply of electrodes and additives, etc.

On the basis of Prigogine principle – the minimum production of entropy applicable to non-equilibrium physical-chemical processes proceeding at a constant speed, we can speak of the predominance of heterogeneous sequential crystallization, which is energetically more advantageous than the bulk homogeneous solidification, and the existence of both mechanisms in competitive interaction and the dominance of heterogeneous crystallization.

The dynamics of supercooling at the interface between the phases and in the melt volume of the welding-surfacing bath, as part of the process of cooling and crystallization of the welding or surfacing seam, can be different, due to a change in the chemical composition in the interphase boundary zone in the process of separation diffusion and supercooling degradation on one side and introducing, for example, filler material into the tail part of the bathtub on the other side. It should also take into account the release of heat in the latent heat of fusion during crystallization at the interphase boundary, which also reduces the actual supercooling of the melts in the active growth zone of the crystals. This is typical for both heterogeneous and homogeneous crystallization. A significant difference in the process of crystallization of the melt of a welding-surfacing bath is the instability of the chemical composition of the melt in the crystallization region, associated with the supply of filler materials, the transition of chemical elements from protective media, the burning out of the melt components during the transition through the arc, the incompleteness of the reactions of chemical interaction due to the short-term metallurgical processes in melt the bath. A number of melt components in the crystal growth zone change the position of the non-equilibrium liquidus, both toward its growth and decrease.

Thus, control of surface formation and formation of specified properties, when restoring parts by surfacing, is quite a complex and urgent task.

The advantages of the proposed technology. The technological process of machining parts after overlayingincludes, mainly, turning with tools with plates of superhard materials, as well as preliminary and final grinding operations. Typically, the processing of such parts is associated with certain difficulties due to the increased hardness of the material being processed. In some cases heat treatment (tempering) is applied, after which it becomes possible to turn or milling with sufficiently low resistance of cutting tools.

New technologies combining several types of energy [4, 5] may prove to be the most effective in solving such a complex multi-criteria problem. These methods include frictional processing combined with high-speed cutting. The friction disc is heated and the reduced surface of the part is pre-treated, after which the final processing is performed by the cutting tool at high speeds. Also perspective is the combined processing methods based on the mechanism of cutting thermo-friction cutting at low speeds [6-9], such as multi-blade rotational turning [10, 11], rotational-friction turning [12, 13], thermos-friction milling and of the interval [14, 15].

The main advantage of these processing methods is the provision of high accuracy and quality of processing at a lower cost of operations due to the use of cutting tools made of non-instrumental materials. And also, with the right choice of optimal cutting conditions, the treatment with the proposed methods eliminates the need for the finishing operation - grinding.

Mathematical modelling of thermal processes. To ensure optimal conditions and processing conditions, it is necessary to strive to ensure optimal temperatures in the cutting zone [16-18]. The proposed mathematical model of thermal processes in the tool and the part allows us to calculate the temperatures in the contacting bodies by calculation and to provide close values to optimal. In frictional processing, the thermal action process is characterized by two modes, such as unsteady and steady. The unsteady mode takes place at the beginning of the processing, when the part and the tool begin to interact. To develop a mathematical model of thermophysical processes, it is necessary to schematize the process.

Taking into account the schematization, the part can be represented as a half-space, on the surface of which a linear thermal source of length B, with an intensity q1, moves with velocity S_m with boundary conditions of the second kind [17, 19]:

$$q_1=\varphi(x,y,z,\tau)=0,$$

that is, the law of distribution of heat fluxes.

Initial conditions:

$$f_o(x,y,z)=\Theta_o\ ,$$

where Θ_o – the ambient temperature, (Θ_o=20°C).

Formula for calculating temperature:

$$\theta(x,z)=\frac{q_1}{\pi\lambda}\exp\left(-\frac{S\cdot z}{2\omega}\right)K_o\left(\frac{S}{2\omega}\sqrt{x^2+z^2}\right) \tag{1}$$

The friction disk is represented as a wedge with an angle of 90 °, on the edge of which there acts a fixed, linear, continuously operating thermal source with intensity q_2.

$$\theta(x,z,\tau)=\frac{q_2}{4\pi\lambda_1}\left(-E_i\left[\frac{R^2}{4\omega_1\tau}\right]\right) \tag{2}$$

where $R^2=x^2+y^2;\ \tau=L_\partial/S$.

where L_l – length of the surface to be treated, m; S – feed, m/sec; q_1- the heat release density of the source acting on the chips, W/m^2; E_i – Euler function; x, z – coordinates of the point under study, m; ω_1 – coefficient of thermal diffusivity of the material of the disk, m^2/sec; λ_1 – coefficient of thermal conductivity of the material of the disk, W/m°C; τ – time of action of the source, sec.

Since the heat source is located at the tip of the wedge, the thermal regime in it, taking into account the effect of the reflected sources, can be written as:

$$\theta(x,z,\tau)=\frac{q_2}{\pi\lambda_1}\left(-E_i\left[\frac{R^2}{4\omega_1\tau}\right]\right) \tag{3}$$

To determine the heat release density q_1 and q_2, it is necessary to solve the heat balance problem, which determines the amount of heat entering the workpiece and the friction disk. To solve the balance problem, boundary conditions of the fourth kind are used, according to which there exists an equality of the mean or maximum temperatures within the contact area of two bodies.

We introduce the notation:

$$\psi_1=\frac{1}{\pi\lambda}\exp\left(-\frac{S\cdot z}{2\omega}\right)K_o\left(\frac{S}{2\omega}\sqrt{x^2+z^2}\right) \tag{4}$$

$$\psi_2=\frac{1}{\pi\lambda_1}\left(-E_i\left[\frac{R^2}{4\omega_1\tau}\right]\right) \tag{5}$$

The coordinates of points for which it is necessary to calculate the temperature lie on the surface, i.e. x = 0. At a point with the coordinate z = 0, the Euler and Bessel functions tend to infinity, therefore it takes z = 0.05.

Taking into account formulas (4) and (5), the system of equations will have the form:

$$\begin{cases} q_1 B + q_2 \pi D = P_z V \\ \psi_1 q_1 = \psi_2 q_2 \end{cases} \quad (6)$$

Solving the system of equations, we calculate accordingly the values of q_1 q_2, which determine the heat fraction for calculating the temperature of the part and the friction disk:

$$q_1 = \frac{P_z V}{\left(B + \frac{\psi_1 \lambda_2}{\psi_2 \lambda_1} \pi D_{фр} \right)} \quad (7)$$

$$q_2 = q_1 \frac{\psi_1}{\psi_2} \quad (8)$$

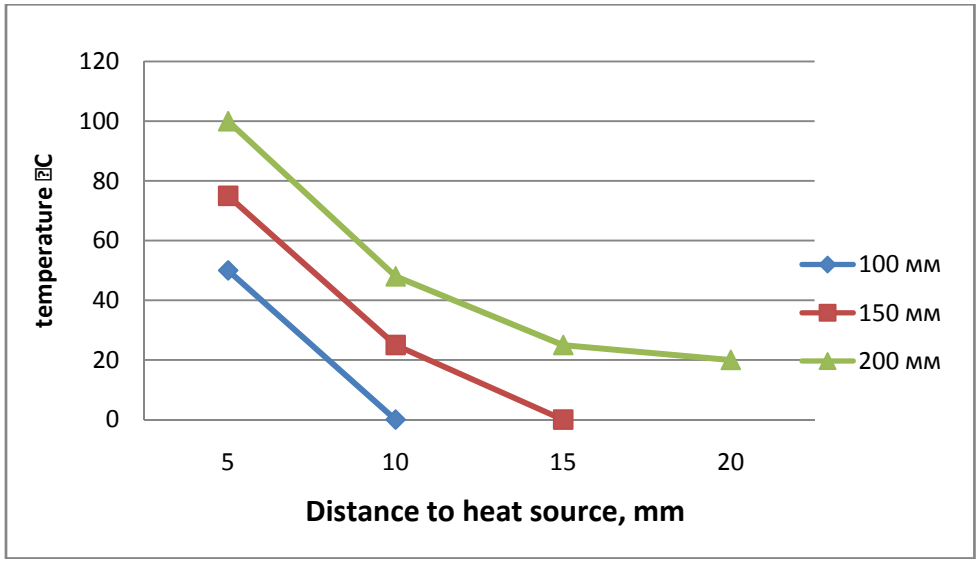
With tool diameter D = 500 mm with cutting modes V = 10 m/s, S = 60 mm/min, the heat balance was 93% and 7%, respectively. 93% enters the body of the friction disk and dissipates in it by thermal conductivity. The remaining 7% of the heat goes to the heating of the part. Knowing the ratio of the amount of heat entering into the contacting bodies, it is possible to determine the surface temperature of the workpiece and, through changing the cutting conditions, ensure the optimum temperature in the contact zone.

It has been experimentally established [17, 20] that the temperature field in the instrument is determined by a number of factors: the operating time, the thermo-physical and physical-mechanical characteristics of the instrumental and processed materials; intensity of heat release, dimensional characteristics of contacting bodies.

The operating time of the friction disc determines the length of the machined surface and the cutting modes.

Figure shows the plot of the heating temperature of the disk from the distance to the heat source.

The graph (see the figure) characterizes quite a sharp drop in temperature as you move away from the heat source. Relatively high temperatures remain at a distance R<10 mm, after which a sharp decrease is observed. The maximum value of the instrument's heating temperature during the entire period of resistance did not exceed 90°C. The average value of the disk heating temperature was 70÷75°C.



Dependence of the heating temperature of a disk from the distance to the heat source

Conclusions.

1. Friction machining is the most effective and economically profitable way of forming a part that has been repaired by overlaying, ensuring uniform heating of the surface and at the same time removing the defective layer.

2. Heating the surface takes place in two modes: stationary and non-stationary. The non-stationary mode takes an insignificant period of time and depends on the cutting regimes, thermo-physical and physical-mechanical characteristics of the contacting pair.

3. As a tool material for the friction disk, it is recommended to choose materials with a high coefficient of thermal conductivity, as they increase the heat flow into the body of the tool and actively exchange heat with the environment. It is also necessary to take into account the thermo-physical characteristics of the material being processed to ensure the optimum temperature in the disk-part pair.

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БАЛҚЫМА ҚАПТАУМЕН ҚАЛПЫНА КЕЛТІРІЛГЕН ТЕТІКТЕРДІ ӨҢДЕУ КЕЗІНДЕ ПІШІНҚАЛЫПТАСТЫРУДЫ БАСҚАРУ

Аннотация. Берілген жұмыста бөлшекті балқыма қаптаумен қалпына келтіру кезіндегі бет пішіннің жасалуын басқару және берілген қасиеттерді қалыптастыру сұрақтары қарастырылған. Балқыма қаптаумен қалпына келтірілгенбөлшектің пішінің жасаудың экономикалық тиімді әдісі ретінде автормармен фрикциялық өңдеу әдісі ұсынылған. Құрал мен бөлшектергі жылулық үрдістердің математикалық үлгісі даярланды, ол түйісуші денелердегі температураны есептік жолмен анықтауға және онтайлыға жақын мәнді қамтамасыз етуге мүмкіндік береді.

Құралдағы температуралық өріс бірқарат факторлармен анықталатыны тәжірибелік анықталды, ол факторларға: жұмыс уақыты, құралдық және өңделуші материалдың жылулық-физикалық пен физикалық-механикалық сипаттары, жылу бөлінудің қарқындылығы, түйісуші денелердің өлшемдік сипаттамалары жатады.

Сұлбалауды ескеріп үлгілеу кезінде бөлшек жарты кеңістік түрінде болады, оның бетімен ұзындығы B, қарқындылығы q_1, жылдамдығы $S_м$ екілік типті шекаралық жағдайға ие болатын сызықтық жылу көзі орын ауыстырады.

Сонымен қоса, дискінің қызу температурасының жылулық көзге дейінгі арақашықтыққа тәуелділік графигі келтіріледі. Температураның айтарлықтай тез төмендеуі жылулық көзден алыстауына байланысты болатыны анықталды. Салыстырмалы жоғары температура R<10 мм қашықтықта сақталады, содан кейін тез төмендеу байқалады. Құралдың қызу температуасының ең көп мәні тұрақтылықтың барлық кезең барысында 90°С аспады. Дискінің қызу температурасының орташа мәні 70÷75 °С құрады.

Түйін сөздер: балқыма қаптау, фрикциялық өңдеу, температуралық өріс, жылулық көзі, фрикциялық диск, жылуөткізгіштік, термофрикциялық кесу.

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УПРАВЛЕНИЕ ФОРМООБРАЗОВАНИЕМ ПРИ ОБРАБОТКЕ ДЕТАЛЕЙ, ВОССТАНОВЛЕННЫХ НАПЛАВКОЙ

Аннотация. В данной работе рассмотрены вопросы управления формообразованием поверхности и формирования заданных свойств при восстановлении деталей наплавкой. В качестве экономически выгодного способа формообразования восстановленной наплавкой детали авторами предложен способ фрикционной обработки. Разработана математическая модель тепловых процессов в инструменте и детали, которая позволяет расчетным путем определять температуры в контактирующих телах и обеспечивать значения, близкие к оптимальным.

Экспериментально установлено, что температурное поле в инструменте определяется рядом факторов: временем работы, теплофизическими и физико-механическими характеристиками инструментального и обрабатываемого материалов; интенсивностью тепловыделения, размерными характеристиками контактирующих тел. При моделировании с учетом схематизации деталь представлена как полупространство, по поверхности которого перемещается линейный тепловой источник длиной B, интенсивностью q_1, со скоростью $S_м$, с граничными условиями второго рода.

Также приводится график зависимости температуры нагрева диска от расстояния до теплового источника. Установлено, что достаточно резкое снижение температуры происходит по мере удаления от теплового источника. Относительно высокие температуры сохраняются на расстоянии R<10 мм, после чего наблюдается резкое снижение. Максимальное значение температуры нагрева инструмента в течение всего периода стойкости не превышало 90°С. Среднее значение температуры нагрева диска составило 70÷75 °С.

Ключевые слова: наплавка, фрикционная обработка, температурное поле, тепловой источник, фрикционный диск, теплопроводность, термофрикционное резание.

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REFERENCES

[1] Panteleenko F.I., Lyalakin V.P., Ivanov V.P., Konstantinov V.M. Restoration of machine parts: Reference book. M.: Mechanical engineering, 2003. 672 p. (in Rus.).

[2] Ivanov V.P. Restoration of worn parts by automatic vibro-arc surfacing. Chelyabinsk, 1976. 207 p. (in Rus.).

[3] Potapov A.K. Restoration of worn parts by surfacing with tubular electrodes. M.: TsBTI, 1980. 33 p. (in Rus.).

[4] Kiryushin D.E., Kiryushin I.E. High-speed face milling of titanium alloys // STIN. 2008. N 7. P. 29-32. https://doi.org/10.3103/s1068798x08100237 (in Eng.).

[5] Kiryushin I.E., Kiryushin D.E. High-speed processing of hard-to-process materials: monograph. Saratov: Sarat. state tech. university, 2009. 148 p. (in Rus.).

[6] Kushnazarov I.K., Goldenberg A., Mussaev F. Method of cutting metal blanks // Patent No. 2738 UZ. Special Herald. 1995. N 3. P. 33-34 (in Rus.).

[7] Alikulov D.E., Muravev O.P., et al. Method of thermofriction treatment of the plane and the design of the friction disc // Innovative patent No. 22998 of the Republic of Kazakhstan for invention on 15.10.2010. Bul. N 10 (in Rus.).

[8] Buzauova T.M., Imasheva K.I., et al. A method of thermofriction cutting-hardening treatment of cylindrical surfaces and the design of a friction disc // Innovative patent No. 25649 of the RK for an invention. 16.04.2012. Bul. N 4.

[9] Mazdubay A.V., Donenbaev B.S., Musaev M.M., et al. The method of thermofriction cutting of metal blanks with cooling and the design of a circular saw // Patent No. 31934 RK for an invention. 03/30/2017. N 6.

[10] Kushnazarov I.K., Mardonov B.T. Improving the quality of the treated surface in multi-rotational rotary turning // Higher school publisher. Proceedings of universities. Tashkent, 2001. N 1. P. 43-44.

[11] Khodzhibergenov D.T., Esirkepov A. Russian Engineering Research. Allerton Press, Inc. 2015. Vol. 35, N 1. P. 43-45. https://doi.org/10.3103/s1068798x1501013x (in Eng.).

[12] Rakishev A.K. Chip formation rotational-frictional turning cylindrical surfaces of agricultural machinery parts // Modern science success journal. Belgorod, 2017. Vol. 1, N 5. P. 104-111 (in Eng.).

[13] Sherov K.T., Sikhimbayev M.R., Sherov A.K., Mazdubay A.V., Rakishev A.K., et al. Matematical modeling of thermofrictional milling process using ANSYS WB software // Journal of Theoretical and Applied Mechanics. Sofia, 2017. Vol. 47, N 2. P. 24-33. https://doi.org/10.1515/jtam-2017-0008 (in Eng.).

[14] Sikhimbayev M.R., Donenbayev B.S., Ainabekova S. Experimental Research of Rotational-and-Frictional Boring of Big Holes in Large Parts // Journal of Theoretical and Applied Mechanics. Sofia, 2017. Vol. 47, N 4. P. 23-36. https://doi.org/10.1515/jtam-2017-0018 (in Eng.).

[15] Sherov K.T., Alikulov D.E. Control ruler for angles between planes of V-shaped guides // Measurement Techniques. July 2012. Vol. 55, Issue 4. P. 397–399. https://doi.org/10.1007/s11018-012-9971-5 (in Eng.).

[16] Kurmangaliyev T.B., Sikhimbayev M.R., Sikhimbayeva D.R., et al. (2018). Experimental study of optimal parameters of pneumatic motor of vibration table for inertial vibroabrasive machining the parts on the basis of beryllium oxide // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical sciences. 2018. Vol. 5, N 431. P. 184-191. https://doi.org/10.32014/2018.2518-170X.24. ISSN 2518-170X (Online). ISSN 2224-5278 (Print) (in Eng.).

[17] Nasad T.G. Surface quality after high-speed heat treatment // Mechanical engineering technology. 2004. N 3(27). P. 11-13 (in Rus.).

[18] Reznikov A.N., Reznikov L.A. Thermal processes in technological systems. M.: Mechanical engineering, 1990. 288 p. (in Rus.).

[19] Sherov K.T., Sikhimbayev M.R., Absadykov B.N., Sikhimbayeva D.R., Buzauova T.M., Karsakova N.G., Gabdysalyk R. Control's accuracy improvement and reduction of labor content in adapting of ways of metalcutting tools // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical sciences. 2018. Vol. 6, N 432. P. 170-179. https://doi.org/10.32014/2018.2518-170X.47 ISSN 2518-170X. (Online). ISSN 2224-5278 (Print) (in Eng.).

[20] Kazinsky A.A., Nasad T.G. Improving the performance characteristics of machine parts reconstructed using the surfacing method. // Improving the reliability and safety of transport facilities and communications: Sat. tr. III Intern. scientific-practical Conf. Saratov, Nov. 15-16. 2017. 2017. P. 231-236 (in Rus.).

[21] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[22] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[23] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[24] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[25] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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TRADE-OFF TRANSPORTATION PROBLEM

Abstract. The purpose of the work is to offer a new solution to the transportation problem. The article looks into a new type of transportation problems that take into account supply and demand. The classical transportation problem expresses the interests of one party - goods supplier. Supply and demand exist in real market conditions. The article introduces a new concept of dual transportation problem. Double transportation problem respects the interests of supplier and consumer. Such problem is called double, since it gives two solutions. The article analyzes different criteria for solving game-theoretic problems and chooses a suitable method for solving a transportation problem. The article provides a solution to the transportation problem based on pure strategies using the minimax criterion. Solving a double transportation problem allows finding the saddle point. The saddle point determines the equilibrium point between supply and demand and is a market solution to the transportation problem. This approach gives more possibilities for solving transportation problems in market conditions.

Keyword: transport problem, optimal solution, game theory, demand. proposal, optimization.

Introduction. Mathematical linear programming problem is called a transportation problem (Monge – Kantorovich) (Rachev, 1985, Levin, 2006). The problem situation is that there are many cargo or goods suppliers and many consumers. Transportation problem involves finding an optimal cargo transportation plan from suppliers to points of consumption with minimal transportation costs (Benamou, Brenier, 2000). Transportation problem is called unbalanced or open if the total volume of cargo offers is not equal to the volume of demand, necessary for points of consumption. A classical transportation problem is a problem with two types of optimality criteria. The first type is a cost criterion that requires a minimum of transportation costs. The second type of criteria is a time criterion that requires a minimum of transportation time. In logistics, the second criterion is implemented as a “just in time” paradigm (Aycock, 2003).

The title ‘transportation problem’ includes a wide range of problems with a general mathematical model (Champion, De Pascale, 2010, Chang et al., 2010, Davidsson, P., et al., 2005). These problems are solved by linear programming methods (Dantzig, 2016). Solving the problem involves optimization methods. The classical transportation problem can be solved by the simplex method (Nelder, Mead, 1965, Tsvetkov, 2001). Taking into account the specifics of the transportation problem provides additional solutions. Currently there are many fuzzy transportation problem options. A common weakness of stating and solving the transportation problem is that it is not a market one.

The classical transportation problem represents the interests of one market participant and characterizes the market supply. Besides supply, there is demand in the market, which is an equally important independent factor. This factor is disregarded when solving transportation problems. Such information situation gives rise to looking into a transportation problem, factoring in both supply and demand. Such a transportation problem can be called a double one, since it provides two solutions: one for the supplier, and one for the consumer.

Game-Theoretic Approach when Solving the Transportation Problem. Conditions for solving a matrix problem can be called an information situation (Tsvetkov, 2012). An information situation is a model of conditions for solving a problem or a model of a situation, under which a problem must be solved. The game-theoretic approach (Friedman, 1990, Camerer , 2011) accounts for the interests of two

parties. Therefore, it can be used to analyze solutions of an open transportation problem. The game-theoretic approach takes into account market demand and supply. To support decision-making, game theory uses a set of mathematical models and rules for their application under uncertainty. Along with the rules, the game may be characterized by the goals that each player seeks to achieve. To achieve the goals, the player employs strategy, tactics and prompt actions. This approach brings the game theory and management together.

In game theory, strategy is defined as a generalized plan for achieving one or several goals. In solving a transportation problem, it is a basis (Tsvetkov, 2001). The following methods are used for solving a transportation problem: the potential method, the Vogel's method (Samuel, Venkatachalapathy, 2011) and others.

Decision-making in game theory means an analytical approach to choosing the next best (Trizano-Hermosilla, Alvarado, 2016) or an action sequence (Tikhonov, Tsvetkov, 2001). In solving a transportation problem, it is called an optimal plan. Transportation problem is described based on the matrix model. Game theory calls such problems matrix games. Matrix game (Vijay, et al., 2005) – is a matrix model representing a two-player zero-sum game. In a matrix game, the strategies of one player A are displayed as rows, and the strategies of another player B are displayed as columns. For the purpose of a transportation problem, let us consider the option when player A represents demand, and player B represents supply. Matrix entries $a_{ij}$are called gains or payoffs, which is why the matrix of relations between the players is called the payoff matrix (figure 1). Hereinafter we will denote the payoff matrix as AA. Additionally, the matrix is also called the decision matrix.

	B_1		B_n
A_1	a_{11}		a_{n1}
		a_{ij}	
A_m	a_{m1}		a_{mn}

Figure 1 – Payoff Matrix

Figure 1 shows a decision matrix with an auxiliary column on the left and an auxiliary row at the top. These column and row show the interests of consumers A and the interests of suppliers B.

In game theory, strategy A is seen as an action, another strategy Bas a reaction. Sometimes each cell or column of a matrix is characterized by a possible state called an external state. In this case, in addition to the gain, each cell of the matrix will have another characteristic - the probability of an external state. Let's denote the probability of external state F_j as q_i – (figure 2). Figure 2 shows a payoff matrix with states.

	$B_1 F_1$	$B_i F_j$	$B_n F_n$
A_1	$a_{11} q_1$		$a_{n1} q_n$
		$a_{ij} q_i$	
A_m	$a_{m1} q_1$		$a_{mn} q_n$

Figure 2 – Payoff Matrix with Payoff and State Values

It is proved for matrix games that any of them has a solution. A solution can be found by reducing the game model to a linear programming problem. Transportation problem is also solved by linear programming methods; therefore, the information situation taken has algorithmic similarity, but a different problem statement.

Finding Tradeoff Solutions. In the payoff matrix (figure 1) solutions are found based on certain rules or criteria. In game theory, there are several proven criteria used in decision-making. Each criterion

is based on a particular strategy and applies under specific conditions. For the sake of simplicity, further analysis is carried out for strategy *A*, while strategy *B* is considered to be opposing. Strategy *A* involves cash payment, while strategy *B* can only agree or disagree with the payment. There are a number of criteria for finding solutions for the payoff matrix (figure 1). Let's highlight some of the criteria.

The minimax principle (MM) (Lehmann, Romano, 2005). According to this criterion, strategy *A,* where the minimum gain is maximum, is chosen as the optimal strategy. Consumers most often use this criterion.

The Bayes–Laplace Criterion (Aldrich, 2008). The criterion is based on calculating the average gain for each row of the payoff matrix and choosing the maximum therefrom. Consumers do not use this criterion when the demand can be fully met.

The Savage criterion (Tikhonov, Tsvetkov, 2001). The concept of risk is introduced in the statistical decision theory. Savage's criterion is also called Savage's minimax risk criterion. Consumers do not use this criterion when the demand can be fully met.

The Hurwitz criterion (Gil, et al., 2004). Hurwitz suggested a criterion at a point lying between the point of view of extreme optimism and extreme pessimism.

The Hodges–Lehmann criterion (Tikhonov, Tsvetkov, 2001). The criterion is based simultaneously on the MM criterion and the Bayes-Laplace criterion. The ν parameter expresses the degree of confidence in the probability distribution used. If confidence is high, the Bayes-Laplace criterion will dominate, otherwise the – MM-criterion will.

Application of the Minimax Principle for Solving a Double Transportation Problem. Pursuant to the criterion, the rule for finding a solution to the transportation problem can be interpreted as follows:

One more column with the smallest a_{ir} results of each row is added to the decision matrix. It is then necessary to choose those options, in the rows of which there is the highest a_{ir} value of this column.

With this criterion, the strategy when choosing a solution is based on the fact that player *A* tries to lose as little as possible, that is, to eliminate the risk. This means that a decision maker cannot face a result worse than the one he relies on. This defines the name of this criterion as maximin. It is reasonable to use the maximin (MM) criterion if the following information situation occurs:

1. The possibility of occurrence of external states F_j is unknown;
2. The solution is implemented only once (no refund is possible);
3. It is necessary to eliminate the risk or minimize it.

The use of this criterion is based on consumer *A's* assumption that the supplier will answer every move with a move where the gain is minimal. This is called a pessimistic point of view. Applying the criterion involves analyzing the *AA* payoff matrix.

The first step involves finding the minimum. For each value *i* (*i*= 1, m is the number of rows) the minimum value of the gain is determined depending on the supplier *B*'s strategies used.

$$\alpha = \min_i a_{ij} \quad (i=1,m). \tag{1}$$

The *i* index in the description (1) of the $\min_i$i function defines the search range. In this case, the *i* index varies in rows and the search is made by rows. The search determines the minimum gain for player *A*, provided that he adopts his *i* th pure strategy.

The next step involves searching among these minimum gains. At the second step, such a strategy $i = i_o$ is found, at which this minimum gain will be maximum, i.e.

$$\max_i \min_j a_{ij} = a_{iojo} = \underline{\alpha} \quad \text{(2) is found.} \tag{2}$$

The number $\underline{\alpha}$ defined by the formula (2) is called the net lower value of the game or maximin. It shows what minimum gain consumer *A* can secure himself by applying his pure strategies with all sorts of actions taken by supplier *B*. The value $\underline{\alpha}$ in expression (2) is also called the maximin gain. This strategy guarantees a gain of at least $\underline{\alpha}$.

You can choose supplier *B's* side and reason for it. Supplier *B* should strive to minimize player *A*'s gain by applying its strategies. Therefore, for player *B*, the maximum is found according to expression (3)

$$\alpha = \max_j a_{ij} \tag{3}$$

The max gain of player *A* is determined in expression (3), provided that player *B* applies his *j*th pure strategy, then player *B* searches for his $j = j_1$ strategy where player *A* will receive min gain, i.e. finds

$$\min_j \max_i a_{ij} = a_{ilj1} = \bar{\alpha}. \quad (4)$$

The $\bar{\alpha}$ number, determined from the expression (4), is called the net upper value of the game or the minimax. It shows the maximum gain supplier *B* can secure with its strategies. In other words, consumer *A,* by applying his pure strategies, can secure a gain of at least $\underline{\alpha}$, and player *B,* by applying his pure strategies, can prevent player *A* from gaining more than $\bar{\alpha}$.

The principle dictating the players the choice of appropriate strategies (maximin and minimax) is called the minimax principle.

Solving a Double Transportation Problem in Pure Strategies. Let's analyze the fundamentals of solving a double transportation problem in pure strategies. A zero-sum matrix game of two players *A*, *B*can be considered as follows. Consumer *A* has *m* strategies $i = 1,2,...,m$, supplier *B* has *n* strategies $j = 1,2,...,n$. Each pair of strategies (i,j) is assigned a number a_{ij}, which expresses player *A*′s gain at player *B*'s expense if the first player uses his *i*th strategy, and *B*– his *j*th strategy. Figure 1 shows the payoff matrix.

If we take a look at the payoff matrix *AA* in figure 1, then each matrix game with the *AA* matrix comes down to consumer *A* choosing the A *i*th row, and supplier *Bj*th column. In such a game, consumer *A* gets a a_{ij} gain. In this situation, if $a_{ij} < 0$, this means that consumer *A* pays a sum of $|a_{ij}|$ to supplier *B*. If $a_{ij} > 0$, this means that supplier *B* sells products to consumer *A*for the amount of $|a_{ij}|$. This ends the game. Each player strategy $i=1,m$; $j=1, n$ is called a pure strategy. The main thing in game theory is to find the optimal players' strategies. A player's strategy is considered optimal if application thereof provides him with the biggest guaranteed gain with all sorts of strategies of another player.

Payment matrix game $\underline{\alpha} = \bar{\alpha}$ is said to have a saddle point in pure strategies and the *net valu*e of the game.

$$\upsilon = \underline{\alpha} = \bar{\alpha}.$$

Saddle point – is a pair of pure strategies (i_o,j_o) of players *A* and *B* respectively, when equality $\underline{\alpha} = \bar{\alpha}$ is achieved. In market interpretation, this means finding an equilibrium point between supply and demand. When solving a transportation problem, this concept has the following meaning: if a consumer follows a strategy that corresponds to the saddle point, a supplier cannot do better than follow a strategy that corresponds to the saddle point. Mathematically, it may be written differently:

$$a_{ij0} \le a_{i0j0} \le a_{i0j}, \quad (5)$$

where *i*, *j* – are any pure strategies of players *A* and *B* respectively; (i_o,j_o) – are strategies forming the saddle point. According to (5), saddle element a_{i0j0} is minimal in the i_o th row and maximal in the j_oth column in the *AA* matrix. A saddle point is found by finding the minimum element in each row of the payoff matrix and checking it for being the maximum in its column. If so, it is a saddle element, and a pair of strategies corresponding thereto, forms a saddle point, that is, an equilibrium point between supply and demand.

A pair of pure strategies (i_o,j_o) of consumer *A* and supplier *B*, forming the saddle point, and saddle element a_{i0j0}, are called the equilibrium solution to the transportation problem. At the same time, i_o and $j_o$are called optimal pure strategies of consumer *A* and supplier *B*.

Conclusion. Accounting for the interests of not only the supplier, but also the consumer results in the need to solve the transportation problem of a new type: 'Demand and Supply Transportation Problem' or 'Trade-Off Transportation Problem'. Such a transportation problem can be called a double transportation problem, since it provides two solutions: one for the supplier, and one for the consumer. Game-theoretic methods are used to solve this problem. Using the minimax principle with pure strategies to solve the transportation problem allows for finding a solution to the transportation problem in the form of a saddle point. The saddle point corresponds to the point of market equilibrium between supply and demand and is an equilibrium solution to the transportation problem, while the classical solution to the transportation problem represents the interests of only one party and does not provide an equilibrium solution.

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КОМПРОМИССНЫЕ РЕШЕНИЯ ЗАДАЧ ТРАНСПОРТИРОВКИ

Аннотация. Цель работы – предложить новое решение транспортной проблемы. В статье рассматривается новый вид транспортных проблем, учитывающий спрос и предложение. Классическая проблема перевозки выражает интересы одной стороны – поставщика товаров. Спрос и предложение существуют в реальных рыночных условиях. В статье представлена новая концепция двойной транспортной. Двойная транспортировка учитывает интересы поставщика и потребителя. Она называется двойной, поскольку она дает два решения. В статье анализируются различные критерии решения задач теории игр и определяется подходящий метод решения транспортной проблемы. В статье представлено решение транспортной задачи на основе чистых стратегий с использованием минимаксного критерия. Решение двойной транспортировки позволяет найти седловую точку. Седловая точка определяет точку равновесия между спросом и предложением и является рыночным решением проблемы транспортировки. Такой подход дает больше возможностей для решения транспортных проблем в рыночных условиях.

Ключевые слова: задача транспортировки, оптимальное решение, теория игр, спрос, предложение, оптимизация.

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REFERENCES

Aldrich J. RA Fisher on Bayes and Bayes' theorem // Bayesian Analysis. 2008. 3(1). P. 161-170.

Aycock J. A brief history of just-in-time // ACM Computing Surveys (CSUR). 2003. 35(2). P. 97-113.

Benamou J.D., Brenier Y. A computational fluid mechanics solutiontothe Monge-Kantorovich mass transfer problem // Numerische Mathematik. 2000. 84(3). P. 375-393.

Camerer C.F. Behavioral game theory: Experiments in strategic interaction. Princeton University Press, 2011.

Champion T., De Pascale L. The Monge problem for strictly convex norms in ℝd // Journal of the European Mathematical Society. 2010. 12(6). P. 1355-1369.

Chang L.Y., Srinivasa S.S., Pollard N.S. Planning pre-grasp manipulation for transport tasks // In Robotics and Automation (ICRA), 2010. IEEE International Conference on. (P. 2697-2704).

Dantzig G. Linear programming and extensions. Princeton university press, 2016.

Davidsson P., Henesey L., Ramstedt L., Törnquist J., Wernstedt F. (). An analysis of agent-based approaches to transport logistics // Transportation Research part C: emerging technologies. 2005. 13(4). P. 255-271.

Friedman J.W. Game theory with applications to economics. Oxford University Press, USA, 1990.

Gil J.J., Avello A., Rubio A., Florez J. Stability analysis of a 1 dof haptic interface using the routh-hurwitz criterion // IEEE transactions on control systems technology. 2004. 12(4). P. 583-588.

Lehmann E.L., Romano J.P. The minimax principle // Testing Statistical Hypotheses. 2005. P. 319-347.

Levin V.L. Optimality conditions and exact solutions to the two-dimensional Monge-Kantorovich problem // Journal of Mathematical Sciences. 2006. 133(4). P. 1456-1463.

Nelder J.A., Mead R. A simplex method for function minimization // The computer journal. 1965. 7(4). P. 308-313.

Rachev S.T. The Monge–Kantorovich mass transference problem and its stochastic applications // Theory of Probability & Its Applications. 1985. 29(4). P. 647-676.

Samuel A.E., Venkatachalapathy M. (2011). Modified Vogel's approximation method for fuzzy transportation problems // Applied Mathematical Sciences. 2011. 5(28). P. 1367-1372.

Tikhonov A.N., Tsvetkov V.Ya. Methods and systems of decision support. M.: Max Press, 2001. 312 p. (in Rus.).

Trizano-Hermosilla I., Alvarado J.M. Best alternatives to Cronbach's alpha reliability in realistic conditions: congeneric and asymmetrical measurements // Frontiers in psychology. 2016. 7, 769.

Tsvetkov V.Ya. Mathematical methods of analysis in economics. M.: MAX Press, 2001. (in Rus.).

Tsvetkov V.Ya. Information Situation and Information Position as a Management Tool // European Researcher/ Series A. 2012. 36(12-1). P. 2166-2170.

Vijay V., Chandra S., Bector C.R. (2005). Matrix games with fuzzy goals and fuzzy payoffs // Omega. 2005. 33(5). P. 425-429.

Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

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DETERMINATION OF NATURAL GAS LOSS VALUES BASED ON PHYSICAL SIMULATION OF LEAKAGES FROM THE PIPELINE TO THE MEDIA WITH SUPERATMOSPHERIC PRESSURE USING A VOLUMETRIC-TYPE EXPANDER

Abstract. The operating practice of gas transmission system reflects that one of the major concerns of pipeline companies is through fault, wherethrough considerable amount of gas is lost triggering gas pipeline accidents followed by fires, explosions, and hazardous substances emissions to the environment, which may cause human losses. The gas leak volume depends on varied parameters, particularly the parameters of the defect itself, the operating mode and the ambient medium.

The purpose of the study was to improve methods for determining the natural gas leakage value from pipelines to the media with superatmospheric pressure.

Software-based methods determining the location and gas leak volume enable to keep continuous control and estimate the target values in real time. However, their accuracy depends largely on the equations simplification degree comprised in the used mathematical model. One of the most significant stages in the development of any model is its adaptation based on experimental data.

For obtaining experimental findings, a test installation was exploited, which provides an opportunity to simulate gas leaks from the pipeline under non-steady-state conditions, and define their value by means of a volumetric expander. Based on it, full factorial experiments for two pressure ranges were carried out with subsequent regression analysis of the results and obtaining dependencies of leakage values on pressures at the leak point inside the gas pipeline and in the medium outside of it. Dependencies can be applied to determine the gas leak volume under non-steady-state conditions.

Keywords: leakage, natural gas, gas loss, leak volume, gas pipeline, experimental studies, volumetric-type expander.

Introduction. In order to ensure efficient and safe operation of main gas pipelines, solving timely detection tasks, leakage elimination and determining the natural gas loss value are essential [1].

The most complicated case is the leakage from the buried gas pipelines, since the gas filtration is in the soil, its distribution from the leak point and concentration in the subsurface voids are determined by a great number of factors [2, 3].

Damages to buried gas pipeline occur for the following reasons: physical impact while excavating due to the deviation from safety rules and operational procedures; corrosion damage of metal pipes as a result of violations and/or inadequate control of the technical state during the construction process; joints rupture and stitches opening of pipelines due to the poor construction and installation works [2, 4].

The consequences of natural gas leakage, apart from its loss, are meant to be: structural damage; injuries and human losses due to burning or explosion of the gas-air mixture; financial and economic expenses as a result of gas shortfall to consumers and penalty provisions [5, 6].

At present leakage detection methods can be divided into several types: traditional, hardware and software.

Traditional methods include visual inspection of pipelines.

The hardware examples may include methods fundamentally applying visual, fiber-optic and acoustic devices, samplers, videothermovision survey, wave of pressure detectors and others. However, due to the long mileage of main gas pipelines, the severe climatic conditions and the inaccessibility of substantial amount of linear parts, using most of the described technical facilities seems to be incredibly challenging [7-10].

Software methods enable to keep continuous control, determine the leakage location as well as gas loss values from the pipeline in real time. They are expected to use systems analyzing the deviation obtained from SCADA pumping parameter systems from the calculations collected by preliminary mathematical modeling of gas flow through the pipeline with the use of statistical data [5, 11-13].

The determination accuracy of the location and gas loss values depends on the equations simplification degree applied in the model. The most popular algorithmic methods use simplified gas motion equations in their composition, which enables to increase the speed of their computational solution, although adversely affects the computational accuracy, especially under non-steady-state conditions. Applying dynamic models, which use general gas motion equations in the pipeline and its filtration during propagation in the soil, can improve the computational accuracy of the leak point and the gas loss volume [7, 14].

However, one of the most important stages in the development of any mathematical model is its adaptation based on experimental data. The given article represents the empirical data to adapt the existing dependencies and models for determining the natural gas leak volume to the media with superatmospheric pressure.

Applied research methods. In obtaining experimental data, a test installation was used, which enables to simulate gas leakage from the pipeline with non-steady-state mode to the medium with superatmospheric pressure, and determine their value by means of volumetric expander [15]. On the basis of the installation, full factorial experiments were conducted for two pressure ranges of inside and outside the pipeline.

Data collection, visualization, and export were carried out on the basis of the SCADA Trace Mode software, data conversion was conducted with Matlab R2017a, regression analysis was performed by means of MS Excel.

Further conversion of collected dependencies was performed on the basis of the computerized algebra software Wolfram Mathematica 10.0.

Body. In general, the gas filtration model in soil consists of the equations: continuity, filtration under Darcy's law and the state equation and has the following form [16-19]:

$$\begin{cases} \dfrac{\partial}{\partial t}(\rho_i s_i m_i) + div(p_i \vec{v}_i) = q_i \\ \vec{v}_i = -\dfrac{k}{\mu} f_i(s)[gradP_i - \rho_i \vec{g}] \\ F(P,T,\rho) \end{cases}$$

The simultaneous equation outlined above is non-linear and difficult to solve; therefore, a simplified linear theory is used to describe the problems of one-dimensional filtration.

The most popular methods for determining the natural gas leak volume are algorithmic [6, 20, 21] based on the law of mass or volume conservation ($V_y = Q_ф$) and the formula for pressure variation along the length of the pipeline (figure 1), which is exemplified by solving the following simultaneous equations [20]:

$$\begin{cases} p_в^2 = p_1^2 - 1{,}11 \cdot 10^{-3} \left(\dfrac{0{,}01}{d} + 2{,}9 \cdot 10^{-2} \dfrac{d}{Q_y} \right)^{0{,}25} \dfrac{Q_ф^2}{d^5} l_ф \\ V_y = 1090 \cdot f \cdot p_в \end{cases}$$

where p_1 and $p_в$ – are, respectively, the absolute gas pressure at the beginning of the pipeline section and at the leak point, MPa; d - is an inner pipeline diameter, cm; Q_y – is a commercial gas rate flowing to the

leak point, nm^3/hr; l_ϕ – is a length of the pipeline from the section beginning to the leak point, m; f – is a damage port-hole area, cm^2; 1090 – is a numerical coefficient considering the reduction of existing values, sound velocity in the medium and the coefficient of irregularity in the gas velocity distribution through the cross-section of the port-hole [20].

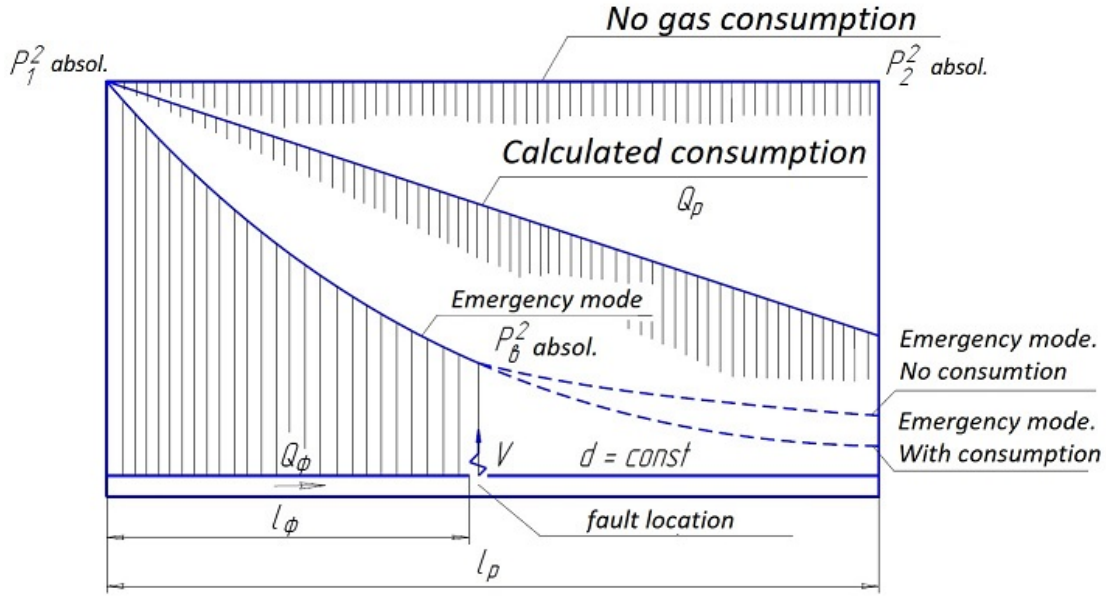

Figure 1 – Pressure variation along the length of the pipeline in the event of an accident [20]

The purpose of the work was to obtain dependencies of the gas loss values from the pressure at the leak point inside the pipeline and in the medium outside of it. Experimental data were obtained on the basis of the installation which has an adjustable volumetric-type expander inward (figure 2) [15].

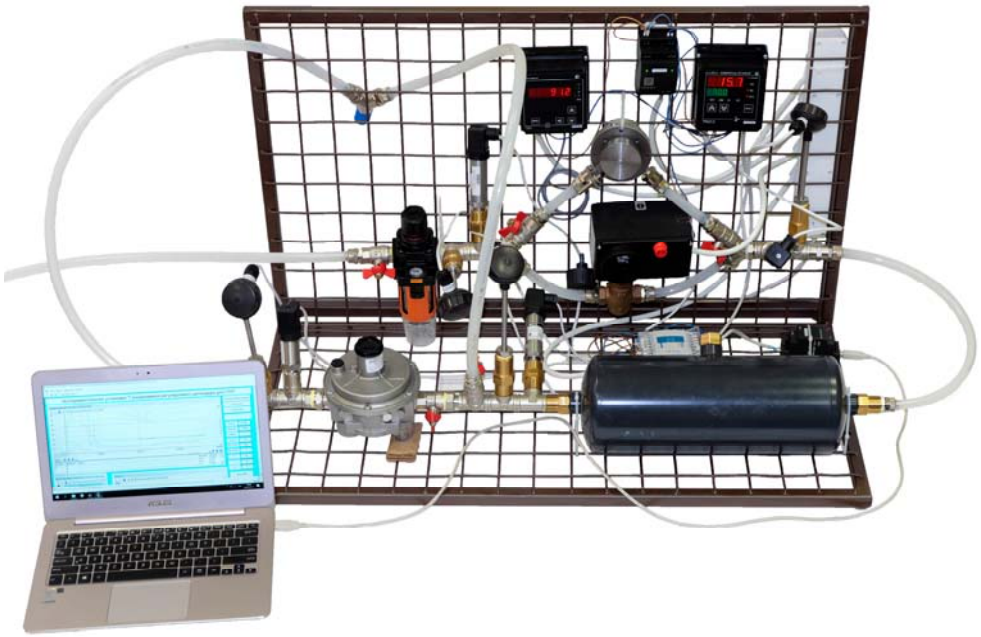

Figure 2 – Test installation

Figure 3 represents the complete diagram of the multifunctional test installation, including the elements that are out of use during the experimental procedure for this performance.

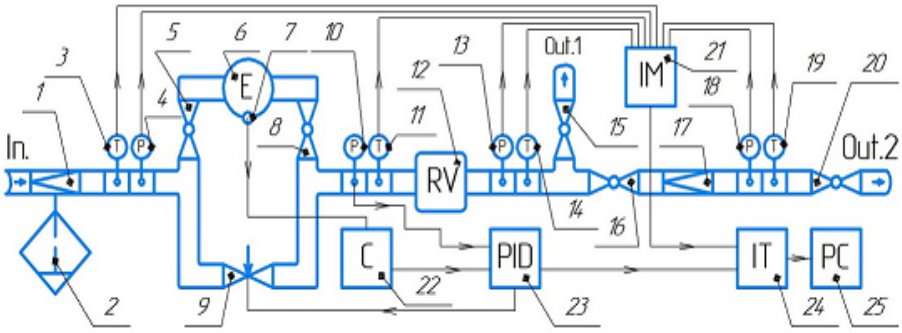

Figure 3 – Test installation diagram

The installation operates in the following manner. After compression by the volume compressor, air gets into pressure regulator 1 and filter separator 2. Nextly, temperature and pressure value measurement is performed by sensors 3 and 4, afterwards the gas flow is divided into two parts proportionally to the rate of opening of the electric control valve 9. One part passes through the volumetric expander 6, which has a contactless frequency sensor 7 fixed on it. The other, respectively, goes through the control valve 9. After the previously separated flows are linked by sensors 10 and 11, pressure and temperature of blended gas stream are measured, further it passes through the receiver 12, and its pressure and temperature are measured once again by sensors 13 and 14. Then, when the tap valve is closed 16, gas is released to the atmosphere by the tap valve 15.

Modeling (maintenance of) a certain pressure in the medium outside the pipeline is in the following way. A signal from pressure sensor 10 is set up to the inlet of the proportional-integral differential controller (PI controller) 23. Depending on the pressure deviation rate for the expander from the programmed constraint, the PI controller 23 sends a guiding signal on the rate of opening of the control valve 9 to its electric driver.

The pressure and temperature transducer readings, frequency sensor 7 and the signal of the rate of opening of the control valve 9 collected by the input module 21 are transmitted via the interface converter 24 to the personal computer 25, where the obtained data are visualized by means of SCADA Trace Mode and exported for further processing. The data collected using SCADA Trace Mode, due to their sizable volume, are exported to TXT or XML file, and then processed using MATLAB R2017a.

Full two-factor experiments were carried out for three-level factors taking into account the effect of their interactions for two pressure ranges (table). Since natural gas in the filtration conditions is under pressure not exceeding 100 kPag [16], the pressure range in the medium beyond the pipeline p_2 was chosen from 45 to 125 kPag. The pressure range at the leak point inside the pipeline p_1 is based on the engineering constraints of the installation.

Experiment Factor Levels

Factor	The factor levels on a natural scale	
	1	2
p_1, kPag	300	400
	350	450
	400	500
p_2, kPag	45	85
	65	105
	85	125

Results. The results of the conducting and processing the obtained data have become dependencies of the expander rotor speed on pressures inside and outside of the pipeline at the leak point $\omega^э(p_1, p_2)$, on the basis of which, target dependencies of the gas loss values were obtained by applying the predeveloped method of calculating basic parameters of the volumetric expansion machine [22, 23], $V(p_1, p_2)$, the visualization of which is represented in figures 4, 5.

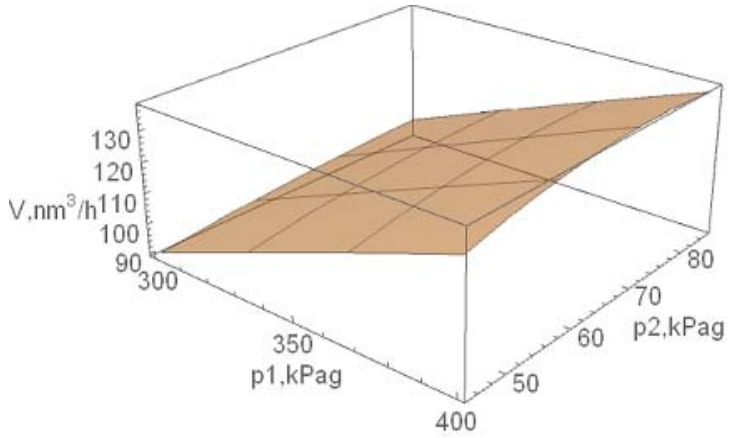

Figure 4 – Dependency visualization of the reduced volume of hourly leakage on pressures at the leak point from the pipeline and in the external medium for the first pressure range

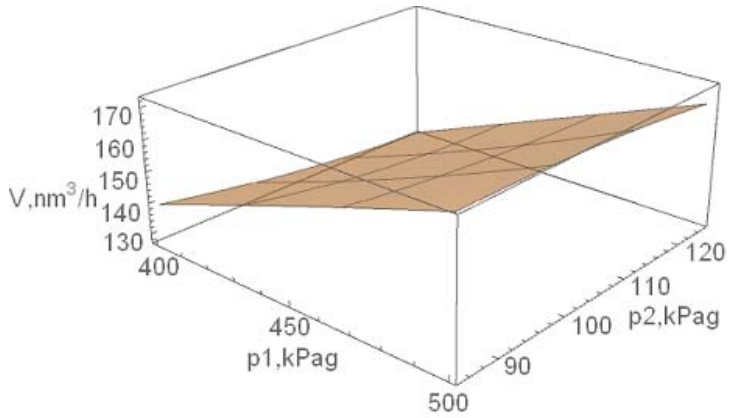

Figure 5 – Dependency visualization of the reduced volume of the hourly leakage on the pressure at the leak point from the pipeline and in the external medium for the second pressure range

The abovementioned dependencies can be used to determine the leakage value under unsteady-state conditions for a certain time t in accordance with the following equation

$$V_{сум} = \int_{t_1}^{t_2} V(p_1^t, p_2^t)dt$$

where p_1^t and p_2^t – are, respectively, the functions of pressure variation inside the pipeline and in the gas filtration medium with time t; t_1 and t_2 – are, respectively, the time points of the beginning and end measurement.

For instance, for the first pressure range (see above) when the pressure variation at the leak point inside the pipeline, according to the following law

$$p_1^t = \left(1 - \sin\left(\frac{2\pi \cdot t}{8760}\right)\right) \cdot p_1^{t_1},$$

where $p_1^{t_1}$ – is a pressure at zero time t_1 equals to 350 kPag, with constant outlet pressure at the level of 65 kPag in an hour the leakage value will be 102.125 nm^3. With $p_1^{t_1} = 450$ kPag and $p_2 = 105$ kPag for the second pressure range is 135.578 nm^3.

Conclusion. By means of the test installation, simulating gas leaks from the pipeline to the media with superatmospheric pressure was carried out. Based on the experimental findings, the dependencies of the leakage value on the pressure at leak point inside the pipeline and in the medium outside of it for two ranges were obtained. Dependencies can be applied to determine the gas leak volume under non-steady-state conditions.

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КӨЛЕМДІК ТҮРДЕГІ ДЕТАНДЕРДІ ПАЙДАЛАНА ОТЫРЫП, АТМОСФЕРАЛЫҚ ҚЫСЫМНАН ЖОҒАРЫ ОРТАҒА ҚҰБЫРӨТКІЗГІШТІҢ ШЫҒЫНЫН ФИЗИКАЛЫҚ МОДЕЛЬДЕУ НЕГІЗІНДЕ ТАБИҒИ ГАЗДЫҢ ЖОҒАЛУ ШАМАЛАРЫН АНЫҚТАУ

Аннотация. Газ тасымалдау жүйесінің нысандарын пайдалану тәжірибесі көрсеткендей, газ компанияларының басты проблемаларының бірі газдың едәуір көлемін өтпелі ақаулар арқылы жоғалту болып табылады, бұл өрт, жарылыс және қоршаған ортаға зиянды заттардың шығарылуына алып келетін газ құбырларындағы авариялarға әкеп соғады, бұл адам құрбандығына әкелуі мүмкін. Газдың шығын көлемі әртүрлі параметрлерге, атап айтқанда ақаудың өзінің параметрлеріне, пайдалану режимі мен қоршаған ортаға байланысты.

Жұмыстың мақсаты атмосфералық қысымдардан жоғары ортаға табиғи газдың құбырөткізгіштен шығу шамасын анықтайтын әдістерді жетілдіру болды.

Газ шығынының көлемі мен орнын анықтаудың бағдарламалық тәсілдері үздіксіз бақылау жүргізуге және нақты уақытта ізделінетін мәндерді есептеуге мүмкіндік береді. Алайда, олардың дәлдігі көп жағдайда қолданылатын математикалық модельдің құрамына кіретін теңдеулерді оңайлату дәрежесіне байланысты. Қандай да бір модельді әзірлеудің маңызды кезеңдерінің бірі оның эксперименттік деректер негізінде бейімдеу болып табылады.

Тәжірибелік деректерді алу үшін стационарлық емес жағдайларда құбырөткізгіштен газдың шығуын моделдеуге, сондай-ақ көлемді детандердің көмегімен олардың шамасын анықтауға мүмкіндік беретін эксперименттік қондырғы қолданылды. Соның негізінде екі қысым диапазоны үшін толық факторлық эксперименттер жүргізілді, кейін олардың нәтижелерін регрессиялық талдау және газ құбырының ішінде және оның сыртындағы ортаға шығу орнында шығын шамасының қысымдардан тәуелділігін алу. Бұл тәуелділік стационарлық емес жағдайларда газдың шығын көлемін анықтау үшін қолданылуы мүмкін.

Түйін сөздер: шығын, табиғи газ, газ жоғалту, шығын көлемі, газ құбыры, тәжірибелік зерттеулер, көлемдік түрдегі детандер.

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ОПРЕДЕЛЕНИЕ ВЕЛИЧИН ПОТЕРЬ ПРИРОДНОГО ГАЗА НА ОСНОВЕ ФИЗИЧЕСКОГО МОДЕЛИРОВАНИЯ УТЕЧЕК ИЗ ТРУБОПРОВОДА В СРЕДЫ С ДАВЛЕНИЯМИ ВЫШЕ АТМОСФЕРНОГО С ИСПОЛЬЗОВАНИЕМ ДЕТАНДЕРА ОБЪЁМНОГО ТИПА

Аннотация. Практика эксплуатации объектов газотранспортной системы показывает, что одной из главных проблем газовых компаний являются сквозные дефекты, через которые теряются значительные объемы газа, что приводит к авариям на газопроводах, сопровождающиеся пожарами, взрывами и выбросами вредных веществ в окружающую среду, что может привести к человеческим жертвам. Объем утечки газа зависит от различных параметров, в частности параметров самого дефекта, режима эксплуатации и окружающей среды.

Целью работы было совершенствование методов определения величины утечек природного газа из трубопроводов в среды с давлениями выше атмосферного.

Программные способы определения местоположения и объёма утечки газа позволяют вести непрерывный контроль и в реальном времени рассчитывать искомые значения. Однако, их точность во многом зависит от степени упрощения уравнений, входящих в состав используемой математической модели. Одним из важнейших этапов разработки какой-либо модели является её адаптация на основе экспериментальных данных.

Для получения опытных данных была использована экспериментальная установка, которая позволяет моделировать утечки газа из трубопровода в нестационарных условиях, а также определять их величину с помощью объёмного детандера. На её основе были проведены полные факторные эксперименты для двух диапазонов давлений с последующим регрессионным анализом их результатов и получением зависимостей величины утечек от давлений в месте утечки внутри газопровода и в среде снаружи него. Зависимости могут быть применены для определения объёмов утечек газа в нестационарных условиях.

Ключевые слова: утечка, природный газ, потери газа, объём утечки, газопровод, экспериментальные исследования, детандер объёмного типа.

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REFERENCES

[1] Sharafiev R.G., Erofeev V.V., Yamurov N.R., Ignatiev A.G. The effect of emergency leaks on average pressure and gas flow in cross-country pipelines in the absence and presence of additional pumping // Vestnik CHGAA. 2014. N 70. P. 141-146 (in Rus.).

[2] Poddubnaya O.S., Martynenko G.N. Simulation of the natural gas distribution processes in the ground // Scientific Journal. Engineering systems and facilities. 2012. 1. P. 43-45 (in Rus.).

[3] Ozhikenov K.A., Mikhailov P.G., Aitimov M.Zh. Design issues of the concept of emergiency monitoring and control system building // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2017. Vol. 1, N 421. P. 34-140. ISSN 2224-5278 (in Eng.).

[4] Bakesheva A.T., Irgibaev T.I. Modern methods for external repair of gas pipelines without interrupting gas pumping // Proceedings of the International Satpaev readings: Scientific heritage of Shakhmardan Esenov. Almaty, 2017. P. 237-239 (in Rus.).

[5] Tevyashev A.D., Gusarova I.G., Kaminskaya A.V. Identification method of the emergency area with regard to the model of non-stationary operating modes of the gas transmission system // East European Journal of Advanced Technologies. 2012. 3. 38-46 (in Rus.).

[6] Kharlamov N.A., Solovyova Y.B. Determination of gas emission values in case of damage to high and medium pressure gas pipelines // Agrarian Scientific Journal. 2015. 2. P. 53-55 (in Rus.).

[7] Korshunov S.A., Chionov A.M., Kazak K.A., Kazak A.S., Kulik V.S. Method for detection of gas leakage in the linear part of the pipeline // Pipeline transport: theory and practice. 2013. 1. P. 14-21 (in Rus.).

[8] Bakesheva A.T., Irgibaev T.I. Technical diagnostics of trunk pipelines using the method of acoustic emission // Proceedings of the international scientific-practical conference: The concept of the development of science and innovation: the view of young scientists. Almaty, 2016 (in Rus.).

[9] Bushmelev P.Yu., Uvaysov S.U., Bushmelev K.I., Plyusnin I.I. Improving the quality of monitoring gas leaks from gas mains through a wireless sensor telecommunications system // Proceedings of the international symposium of reliability and quality. 2015. P. 4-8 (in Rus.).

[10] Barabanov Y.A., Maltsev D. B., Esaulenko V.N., Rudenko M.F. Distributed control system of technological objects of the oil and gas industry based on a wireless sensor network // Vestnik of AGTU. Series: Management, Computer Engineering, and Computer Science. 2017. Vol. 2. P. 98-104. DOI: 10.24143/2072-9502-2017-2-98-104 (in Rus.).

[11] Ksenzov M.V. Determining the location and size of leaks in gas pipelines // Don Engineering Bulletin. 2014. N 4. P. 88-98 (in Rus.).

[12] Kabylbekov K.A., Abdrakhmanova Kh.K., Saidakhmetov P.A., Musaev J.M., Issayev Ye.B., Ashirbaev Kh.A. Calculation and visualization of a body motion under the gravity force and the opposing drag // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 5, N 431. P. 85-94. https://doi.org/10.32014/2018.2518-170X.38. (Online) ISSN 2224-5278 (Print).

[13] Sinchev B., Mukhanova A.M. The design of unique mechanisms and machines. II // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 5, N 431. P. 210-217. https://doi.org/10.32014/2018.2518-170X.27 (Online). ISSN 2224-5278 (Print).

[14] Andrei A.A., Evgenii V.S., Irena V.Y. Justification of representative data volume of porosity and permeability properties for obtaining statistically reliable petrophysical connections // Journal of Mining institute. 2018. 233. P. 487-492. DOI: 10.31897/PMI.2018.5.487 (in Eng.).

[15] Belousov A.E., Samigullin G.Kh. Experimental studies of the natural gas reduction process with associated utilization of its energy using a volumetric-type expander in unsteady conditions // Gorny Analytical Bulletin (scientific and technical journal). 2018. N 5 (special edition 18). P. 20 (in Rus.).

[16] Pavlyukov S.P. Simulation of gas leaks from underground gas pipelines in emergency situations: dissertation, Cand. tech. Sciences: 05.23.03 // VGASU. Voronezh, 2010. P. 119 (in Rus.).

[17] Genbatch A.A., Bondartsev D.Yu. Experimental method of investigation of the heat transfer crisis in a capillary-porous cooling system // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 2, N 428. P. 229-235. ISSN 2224-5278 (in Eng.).

[18] Murtazin E.Zh., Kalugin O.A., Kan S.M. Some features of determining filtration capacity of the soil of low-pressure earth dams // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2015. Vol. 2, N 410. P. 56-61. ISSN 2224-5278 (in Eng.).

[19] Dmitrii A.L., Vladimir V.G. Collaborative interpretation of the data obtained by resistivity and ground penetrating radar methods for assessing the permeability of sandy clay soils // Journal of Mining institute. 2018. 229. P. 3-13. DOI: 10.25515/PMI.2018.1.3 (in Eng.).

[20] Fastov L.M., Solov'eva E.B. Algorithm for solving the problem of determining the volume of emissions (leaks) of gas in the event of damage to gas pipelines // Scientific and technical problems of improving and developing gas energy supply systems. 2006. 1. P. 51-57 (in Rus.).

[21] Karpus N.I. Evaluation of gas losses through defects in the body of the pipeline // Equipment and technologies for oil and gas complex. 2016. 1. P. 50-54 (in Rus.).

[22] Belousov A.E., Samigullin G.K., Kleimenov A.V. Modelling of gasdynamic processes at pressure reduction point with the use of a volumetric expander-generator set to assure safe recycling of the energy of compressed natural gas // Chemical and petroleum engineering. 2018. 54. P. 392-398. DOI: 10.1007/s10556-018-0492-1 (in Eng.).

[23] Lutsenko N.A. Numerical simulation of three-dimensional unsteady gas flow through porous objects with sources of energy release // Computational continuum mechanics, journal series. 2016. 3. P. 331-344 (in Rus.).

[24] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[25] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[26] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[27] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[28] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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PROTECTIVE ZINC COATINGS FROM ACID ELECTROLYTE OF ZINC-PLATING

Abstract. The aim of the work is to select the a combination of surfactants to be introduced into the galvanizing electrolyte in order to obtain uniform, thick, non-porous zinc coatings, with a high probability of protecting the product surface from corrosion in corrosive environments - wet, underground, hot.

The object of research is the process of electrodeposition of zinc from simple sulfate galvanizing electrolytes with a combination of surfactants: succinic acid with urotropin, citric acid with thiourea, at a current density of 1-3 A/dm^2, at a constant fixed pH value at room temperature. For an objective evaluation and comparison of the quality of zinc coatings obtained from electrolyte with combined surfactants, studies of electrolytic zinc production from an electrolyte containing no surfactants were performed. For both cases, an energy-dispersive electron microscopic expertise of zinc coatings was performed and presented in the form of photographs and tabular data. The elemental composition of zinc coatings obtained from electrolyte without surfactant and with combined surfactants is determined and presented. The chemical expertise of the zinc coating was carried out to determine its thickness and porosity. The effective effect of the selected surfactant combination on the quality of the zinc coating is shown. The conclusions are drawn and recommendations are given on the results of the conducted research.

Keywords: sulfate electrolytes, zinc coatings, surfactants (surfactants).

The metallic constructions can be protected from atmospheric, marine, underground, gas and other types of corrosion with the help of various protective coatings: metalic, paint and varnish, etc.

The hot methods for applying metallic protective coatings (methods of immersion in molten metal), diffusion methods, methods of metallization (spraying by compressed air of metal or alloy on the metallic surface), paint coatings, chemical coatings exploitative in different corrosive environments can't effectively to resist the aggressive corrosive environment. Effectively to protect the metallic products from corrosion only by way of electrolytic method applying possibly to their surface of the metallic coatings. The valuable property of the electrolytic method is the opportunity to regulate of the coating thickness, down to fractions of the micron, which allows at coating efficiency of coating to save electrolyte. Electrolytic zinc, copper, chrome, nickel, cadmium galvanic coatings attached to the protected metallic product not only decorative finish (coating color and gloss), but also impart the necessary properties to the coating, such as hardness, porosity, uniformity over the entire surface of the protected product [4, 5].

To receive high-quality cathodic zinc coatings obtained from acidic sulfate electrolyte containing succinic acid as the surfactant in combination with urotropine, reagents of the grade " chemically pure" were used: zinc sulfate, sodium sulfate, aluminum sulfate, surfactants, anodes from electrolytically pure zinc, steel cathodes brand ST-3.

We carried out researches of electrolyte without surfactant to compare the quality of zinc coatings. In the table 1 shows the results of the quality of the zinc coatings obtained from the acid sulfate electrolyte

Table 1 – Zinc coatings obtained from electrolyte without surfactant

I_k, A/dm^2	CO, %	Appearance of zinc coating	Thickness, mkm	Porosity	Scanning electron microscope data JSM-6490LV	
					% impurities in the coating	% Zn in the coating
0,5	76,6	Gray, coarse-grained	24,8	Porous	C, O, Al, Fe - 10,15	89,85
1	76,1	Gray, coarse-grained	23,5	Porous	C, O, Al, Fe - 13	87,0
2	56,2	Dark gray, coarse-grained	21,6	Porous	C, O, Al, Fe - 18	82
3	56,2	Dark-gray, along the edges with cadmium	22,3	Porous	C, O, Al, Fe - 16,93	83,07

without surfactant. External parameters and data's on zinc coating obtained with the scanning electron microscope (% of zinc in the coating) are described, and the calculated values of the zinc current yield are shown.

Protective zinc coatings obtained from electrolyte without surfactants, coarse-grained, porous, with a low current yield (56-75%). At that, than the current density increased, than the coatings darken, peel off along the edges of the coating, and dark molds are formed.

The elemental composition of the zinc coatings described with the JSM - 6490LV of electron microscope from a single coverage area for a current density of 0.5 A/dm^2 is shown in figure 1.

Element	Weightily, %
C	4.76
O	2.00
Al	0.14
Si	0.07
S	0.09
Fe	0.43
Zn	92.51

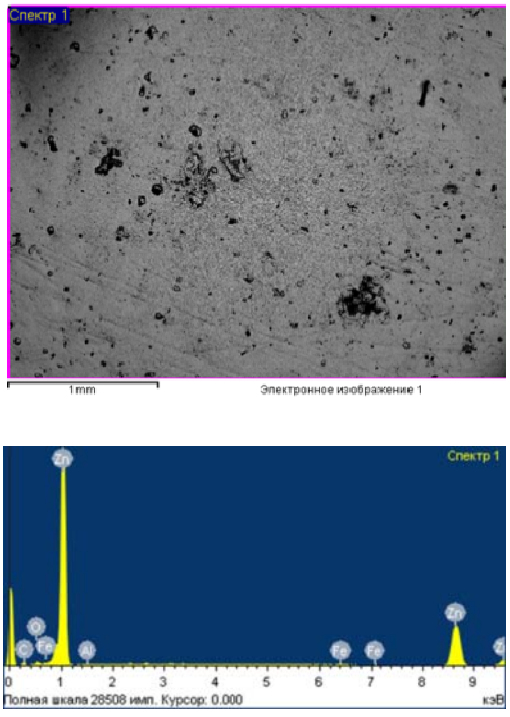
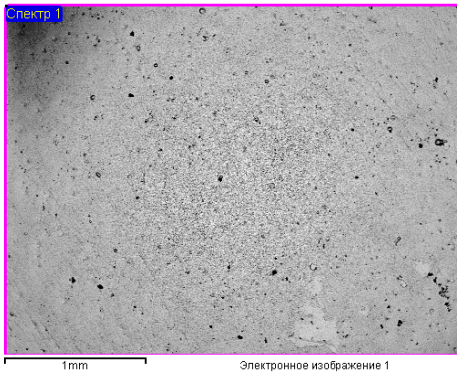


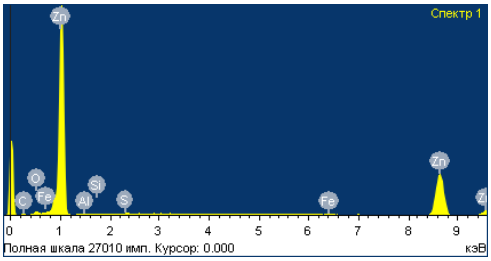
Figure 1 – Zinc coating and its elemental composition in electrolyte without surfactant

An analysis of the elemental composition of the zinc coating shows the content of zinc in the coating. From the electronic photograph, the presence of pores and fuses along the edges of the zinc coating is evident.

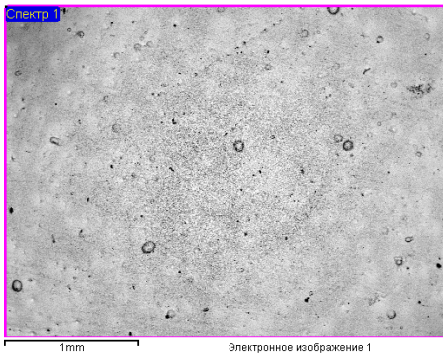
In figure 2 is given the elemental-weight composition of the zinc coatings and the electronic image of the surface of the coating obtained from the electrolyte with surfactant (succinic acid with urotropine) at a current density of 1 and 2 A/dm^2. The content of zinc in the coating is higher, as compared to coatings obtained from electrolyte without surfactant. The zinc coating is light, non-porous, with no fumes. However, the composition of the elements differs from the coating of zinc, obtained without surfactants in the electrolyte. Sera and silicon appear, probably present in the surfactant.

Element	Weightily, %
C	7.62
O	1.53
Al	0.21
Fe	0.79
Zn	89.85





Element	Weightily, %
C	3.50
O	1.11
Al	0.18
Si	0.08
S	0.07
Fe	0.15
Zn	94.91



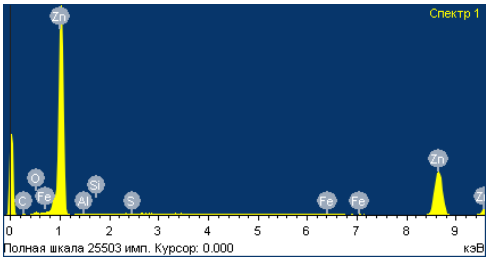


Figure 2 – Zinc coating and its elemental composition
from electrolyte with surfactant at a current density of 1 and 2 A/dm^2

In the table 2 are given the quality indices of zinc coatings obtained from an electrolyte with the surfactants. At the current density of 1 A/dm^2, the coatings are light gray, much lighter when compared to coatings obtained from an electrolyte without surfactant. Non-porous, which have the high current output of 98.6%. At the current density of 2 A/dm^2, the zinc coatings are lighter, non-porous, with a zinc current output of 98.2%. The presence of sulfur impurities: 0.07-0.09% by weight, does not negatively affect the quality of zinc coatings. It is possible that the sulfur impurity has a positive effect in that it promotes more active adsorption of the surfactant on the surface of the article to be protected, crushing and improving the coating structures. It should be noted the high yield of zinc current in the whole investigated current density range (from 90 to 98%).

Table 2 – Quality of zinc coatings from electrolyte with the addition of succinic acid with urotropine

	CO, %	Appearance of zinc coating	Thickness, mkm	Porosity	Scanning electron microscope data JSM-6490LV	
					% impurities in the coating	% Zn in the coating
0,5	92,0	Light Gray	21,68	Non-porous	C, O, Al, S, Fe General : 10,37	88,63
1	98,6	Light Gray	22,36	Non-porous	C, O, Al, S, Fe General 7,49	92,51
2	98,2	Light coloured	23,24	Non-porous	C, O, Al, S, Fe General 5,09	94,91
3	90,7	Light Gray	21,2	Non-porous	C, O, Al, S, Fe General 8,7	91,3

Also was researched the combination of surfactants: citric acid with thiourea in the galvanizing electrolyte. The quality of zinc coatings is given in table 3.

Table 3 – The quality of coatings of zinc and BT in the electrolyte with the addition of citric acid and thiourea

I_k, A/dm^2	CO, %	Appearance of zinc coating	Thickness, mkm	Porosity	Scanning electron microscope data JSM-6490LV	
					% impurities in the coating	% Zn in the coating
0,5	71,6	Dark grey, without fumes	16,04	Porous	C, O, Al, S, K, Fe - 30,06	69,94
1	73,0	Gray, with spots	15,88	Porous	C, O, Al, S, K, Fe - 34,06	65,94
2	68,2	Gray, with spots	15,72	Weakly porous	C, O, Al, S, Fe, K - 30,24	69,76
3	69,3	Dark grey, along the edges of the coke	16,64	Porous	C, O, Al, S, Fe, K - 40,24	59,76

The elemental composition of the zinc coating shows 6.52% by weight of sulfur. Sulfide sulfur in contens in thiourea is probably to have a detrimental effect on the quality of the zinc coating. Coatings at all current densities are dark, porous.

Element	Weightily, %
C	5.53
O	27.29
Al	0.27
S	6.52
K	0.55
Fe	0.07
Zn	69.76

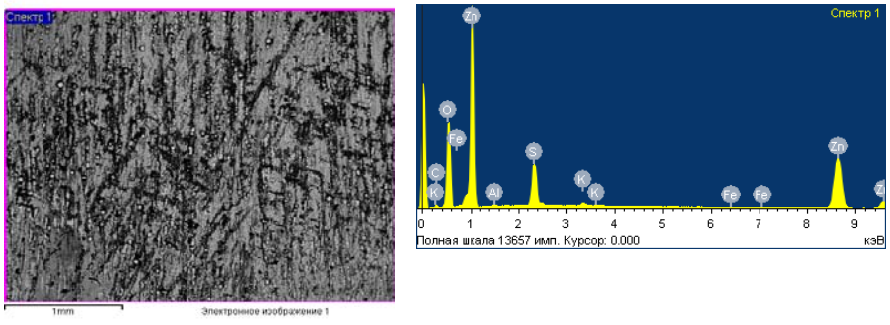


Figure 3 – Zinc coating and its elemental composition from electrolyte with surfactant at a current density of 2 A/dm^2

In all the investigated range of current densities, the current efficiency is low, within 70%. Appearance also does not meet the requirements; zinc coatings are dark, with cracks, with spots. The thickness of the zinc coating is also lower, compared to another combination of surfactants in the electrolyte, all the coatings obtained are porous, which is clearly visible in figure 3.

Conclusions.

1. The conditions of electrodeposition of zinc coatings from electrolyte with combined surfactants are researched.

2. Quality indicators of zinc coatings obtained in the current density range of 0.5-3 A/dm^2 without surfactants and with additives are given.

3. The effective combinations of surfactants in the electrolyte (succinic acid and urotropine) to obtain high-quality zinc coatings are shown.

4. An energy-dispersive electron-microscopic analysis of the composition and appearance of zinc coatings obtained from pure electrolyte and in electrolyte with surfactant has been performed.

5. The optimum mode for obtaining a high-quality zinc coating is shown.

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ҚЫШҚЫЛДЫ МЫРЫШТАУ ЭЛЕКТРОЛИТІНЕН ЖАСАЛҒАН МЫРЫШТЫ ҚОРҒАНЫС ЖАБЫНДЫЛАРЫ

Аннотация. Жұмыстың мақсаты: ылғалды, жер асты, жанғыш – агрессивті орталардағы бұйымның бетін коррозиядан қорғаудың жоғары ықтималдылығымен, қалыңдығы бойынша біртекті, тығыз, кеуек емес мырыш жабындыларын алу мақсатында, мырыштау электролитіне ендіруге арналған беттік белсенді заттардың (ары қарай ББЗ) комбинациясын таңдап алу.

Зерттеу объектісі – қарапайым сульфатты электролиттерді ББЗ комбинациясымен мырыштау кезінде: 1–3 А/дм^2 ток тығыздығындағы, бөлме температурасындғы pH-тың тұрақты белгіленген мәнінде: уротропинді янтарь қышқылымен, тиомочевиналы лимон қышқылымен мырышты электротұндыру процесі болып табылады. Комбинацияланған ББЗ-мен электролиттен алынған мырыш жабындыларының сапасын салыстыру және объективті бағалау үшін, ББЗ-ы болмайтын электролиттен мырышты электролитті алу үшін зерттеулер жүргізілген. Екі жағдайда да мырыш жабындыларының энергодисперсиялық электрондық микроскопиялық сараптамасы жүргізілген және нәтижелері сурет, кесте түрінде келтірілген. Комбинацияланған ББЗ - мен және ББЗ-сыз электролиттен алынған мырыш жабындыларының элементтік құрамы анықталған және келтірілген. Мырыш жабындысының қалыңдығы мен кеуектілігін анықтау үшін оның химиялық сараптамасы жүргізілген. Таңдалып алынған ББЗ комбинациясының мырыш жабындсының сапасына тиімді әсері көрсетілген. Жүргізілген зерттеу нәтижесі бойынша ұсыныстар берілген және қорытынды жасалған.

Түйін сөздер: сульфатты электролиттер, мырыш жабындылары, беттік-белсенді заттар (ББЗ).

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ЗАЩИТНЫЕ ЦИНКОВЫЕ ПОКРЫТИЯ ИЗ КИСЛОГО ЭЛЕКТРОЛИТА ЦИНКОВАНИЯ

Аннотация. Цель работы заключается в подборе комбинации ПАВ для введения в электролит цинкования, с целью получения равномерных по толщине, плотных, беспористых цинковых покрытий, с высокой вероятностью защиты поверхности изделия от коррозии в агрессивных средах – влажных, подземных, горячих.

Объектом исследований является процесс электроосаждения цинка из простых сульфатных электролитов цинкования с комбинацией ПАВ: янтарная кислотас уротропином, лимонная кислота с тиомочевиной, при плотности тока 1–3 А/дм^2, при постоянно фиксируемом значении pH при комнатной температуре. Для объективной оценки и сравнения качества цинковых покрытий, полученных из электролита с комбинированными ПАВ, проведены исследования электролитического получения цинка из электролита, не содержащего ПАВ. Для обоих случаев проведена энергодисперсионная электронномикроскопическая экспертиза цинковых покрытий и представлена в виде фотографий и табличных данных. Определен и представлен элементный состав цинковых покрытий, полученных из электролита без ПАВ и с комбинированными ПАВ. Проведена химическая экспертиза цинкового покрытия для определения его толщины и пористости. Показано эффективное влияние подобранной комбинации ПАВ на качество цинкового покрытия. Сделаны выводы и даны рекомендации по результатам проведенных исследований.

Ключевые слова: сульфатные электролиты, цинковые покрытия, поверхностно-активные вещества (ПАВ).

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REFERENCES

[1] Kovayzina I.I., Naidenova Y.S. Vliyanie PAV na ehlektroosazhdenie cinka iz sul'fatnogo ehlektrolita // Sbornik materialov. Vseros. nauchno-tekhn. konf. Kirov, 2006. P. 77-81.

[2] Pat. 200611438802 RF. Sposob ehlektroliticheskogo cinkovaniya izdelij / Dorod'ko V.V., Solov'yov G.S.; opubl. 27.05.2007.

[3] Hamunela B., Medvedev G.I., Makruchin N.A. Ehlektroosazhdenie blestyashchih cinkovyh pokrytij iz sul'fatnogo ehlektrolita // Uspekhi v himii i him. tekhnologii. 2006. N 9. P. 90-92.

[4] Minin M.V., Solov'eva N.D. Kinetika ehlektrovosstanovleniya cinka iz sul'fatnogo ehlektrolita v prisutstvii dobavok PAV // Vesti SGTU. 2013. N 1. P. 57-62.

[5] Minin I.V. Razrabotka usovershenstvovannoj tekhnologii ehlektroosazhdeniya cinkovyh pokrytij s primeneniem modificirovannyh sostavov ehlektrolitov: Avtoref. … kand. tekhn. nauk. Saratov, 2013. 19 p.

[6] Redjechta A., Loucif K., Mentar L., Redha K. Ehlektroosazhdenie i svojstva plenok iz splava Cu-Zn, poluchennogo iz sul'fatnoj vanny // 2014. N 2. P. 221.

[7] Nakano H., Hisano S., Oue S., KobayashiS., Fukushima H. Povedenie primesi pri soosazhdenii v processe ehlektroliticheskogo cinkovaniya v rasplave v sul'fatnoj vanne v prisutstvii ionov Fe. Japan, 2007. P. 39-43.

[8] Krisha M.M., Assaf F.H., Toghan A.A. Ehlektroosazhdenie Zn-Ni splavov iz sul'fatnoj vanny // J. Solid State Electrochem. 2007. Vol. 11, N 2. P. 244-252.

[9] Muralidhara H.B., Naik Arthoba Y., Venkatesha T.V. Vliyanie produkta kondensacii glicil-glicina i furfurola na ehlektroosazhdenie cinka iz sul'fatnogo ehlektrolita // Bull. mater. sci. 2006. Vol. 29, N 5. P. 497-503.

[10] Pat. 102005002706. Sposob naneseniya pokrytij / Danger E., Pohl M.; opubl. 20.07.2006.

[11] Borisov N.B. Cink na rynke protivokorrozionnyh pokrytij // 2008. N 2. P. 10-12.

[12] Muralidhara H.B., Naik Arthoba Y. Issledovanie nanokristallicheskogo cinkovogo pokrytiya // Bull. mater. sci. 2008. Vol. 31, N 4. P. 585-591.

[13] Wan Renrong, Chen Yong-yan. Sposob ehlektroosazhdeniya Zn s bol'shoj skorost'yu v sul'fatnoj vanne i svojstva pokrytiya. Kit., 2007. P. 65-66.

[14] Muralidhara H.B., Naik Arthoba Y. Ehlektrohimicheskoe osazhdenie nanokristallicheskogo Zn na stal'nuyu podlozhku iz kislogo cinkatnogo rastvora // Surfaceandcoal. 2008. Vol. 202, N 14. P. 3403-3412.

[15] Stefanov Y.S., Valchanova I.D., Magaeva S.D., Dobrev T.S. Issledovaniya kompozicionnyh pokrytij, ispol'zuemyh v kachestve anodov pri ehlektroehkstrakcii Zn iz sul'fatnyh ehlektrolitov. Bulg.: Chem. Commun, 2008. P. 277-280.

[16] Pat. 2007 114428/02. Ehlektrolit blestyashchego cinkovaniya / Vladimirova V.F., Katkova E.A.; opubl. 10.01.2009.

[17] Nakano H., Hisano S., Oue S., Kobayashi S., FukushimaH. Ehlektroosazhdenie kompozita Zn-oksid V iz sul'fatnyh rastvorov. Japan: Iron and steel Inst., 2007. P. 703-708.

[18] Vysoskaya N.A., Kabylbekova B.N., Isabaeva K., Bitanova G.A. Podbor PAV v ehlektrolity cinkovaniya // Trudy mezhdunarodnoj nauchno-prakticheskoj konferencii Auehzovskie chteniya-16. 2018. Vol. 6. P. 89-92.

[19] Kabylbekova B.N., Bekchigitova K.A., Tastanbekov B.M., Karinbaeva M.P. Harakteristika cinkovyh pokrytij, poluchennyh iz kislogo ehlektrolita v prisutstvii kombinirovannyh PAV // Trudy mezhdunarodnoj nauchno-prakticheskoj konferencii Auehzovskie chteniya-16. 2018. Vol. 6. P. 147-150.

[20] Il'in V.S. Cinkovanie. M.: Metallurgiya,1989. 97 p.

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SYSTEM OF THE OIL PUMPING STATIONS' EQUIPMENT PROTECTION FROM HYDRAULIC LOADS

Abstract. In the work analysis of existing systems, methods and devices on protection of the oil pumping station equipment from waves of the high pressure has been made. Mainly, there are equalizations tanks, which are widely used in pipeline systems of low pressure for protection from hydraulic loads. Air chamber allows to smooth waves of the different pressure by the transmission of high frequency pressure fluctuations to the low frequency pressure fluctuations with decreased amplitude. Automated regulation system, implementing the smoothing of pressure waves by throttling of flow with control valves etc. Despite the advantages on struggle with hydraulic loads, they have plenty of existing defects, related to process modes of the oil transportation. For their elimination, it is proposed the protection system, on the basis of which there is a method on smoothing of the pressure pulsation on counter flows. Average speed of the pressure growth, supported by the system does not exceed the allowed, specified in the process regulation of volume 0.03 Mpa/sec. The system can operate in several smoothing modes for provision of reliable protection with different waves intensity of high pressure and switches on self-regulation mode of emission-discharge processes. System efficiency is supported by the automated control system.

Keywords: oil pipeline, pumping station (PS), hydraulic loads, pulsation smoothing, pressure waves, air chamber, equalization tank, flap, valve.

Introduction. For protection of the pipeline from high and low pressure waves, there are existing different technologies, methods, and technical devices, which are permanently being advanced and added with new developments. At the same time, despite the existing progress in solution of the put assignment, many of issues are left open [1-3]. Due to this, advancement of famous and creation of new pressure surge relief system is a crucial task. For comparative analysis, we will consider basic methods and protection devices from hydraulic loads [4].

Methods. *Equalization tank.* Equalization tanks [5,6] are frequently used in pipeline systems of low pressure for protection from high and low pressure waves, appearing in transitional process. In figure 1, there is an example of unidirectional equalization tank, which is vertical pipe of small diameter, connected with basic pipeline. Usually, equalization tank is located near the regulation device, which can be a source of undesirable appearances. Closing of the control element leads to braking of the leakage, in the result of which, pressure in the pipeline is increased. Herewith, leakage starts to leak to equalization tank.

As soon as the leakage arrives to equalization tank, level of the leakage is increased. Because of the reason that the part of leakage gets to the equalization tank, braking of flow slows down and pressure wave amplitude is significantly decreased.

Similar, with opening of control element, the leakage is speed up, and the pressure in the pipeline is decreased, that is why, leakage from equalization tank flows out, partially compensating pressure fall in the internal cavity of pipeline.

In figure 2, there are curve amendments of total head in the pipeline, equipped with equalization tanks, with transitional process, evoked by shut-down of pump. It is shown that with shut-down of pump, at its outlet, pressure is down fast and down the flow, wave of the low pressure is distributed. Taking into

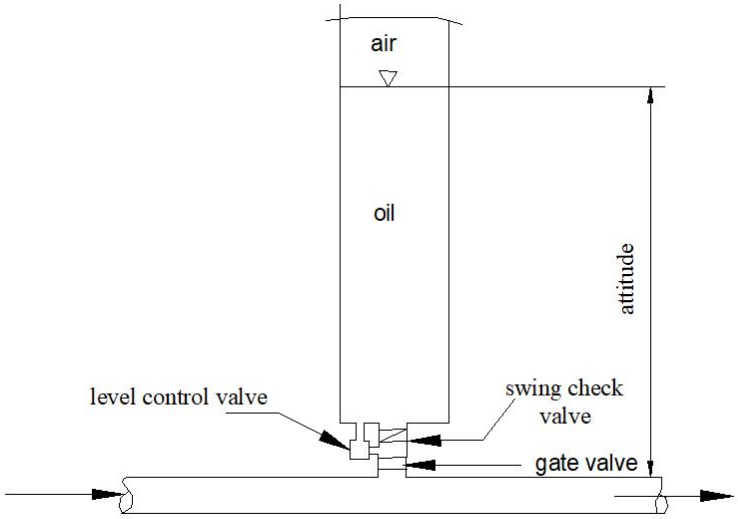

Figure 1 – Unidirectional equalization tank

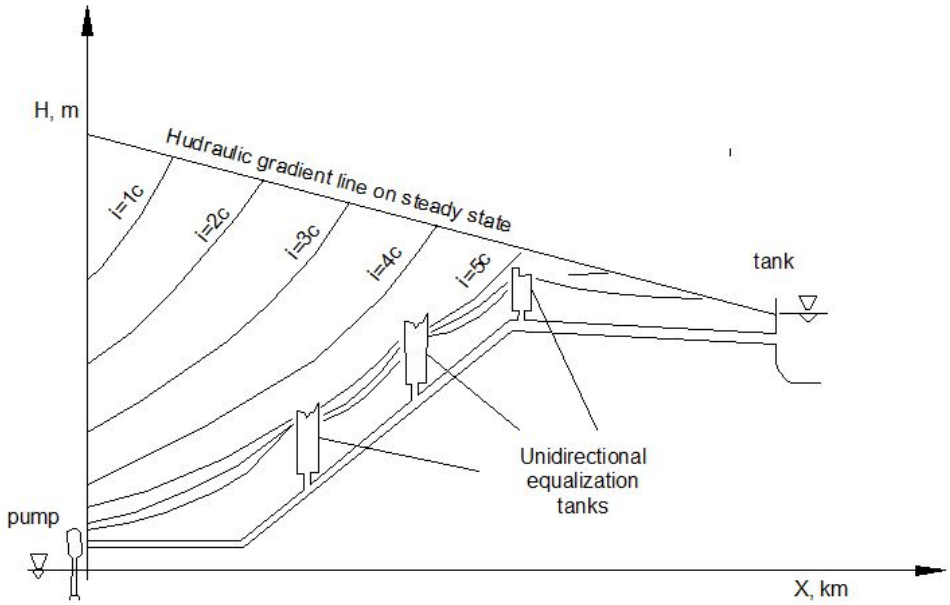

Figure 2 – Amendment of head on length of the pipeline, equipped with three unidirectional equalization tanks

account profile of the considered pipeline, appeared wave leads to pressure decrease in pipe up to the pressure of elastic leakage steams, leading for boiling, which is unacceptable. In order to exclude the possible boiling of leakage in the considered case, three unidirectional equalization tanks are installed on pipeline, which do not allow the pressure in the connected pipeline to decrease lower than the static pressure, which is determined by height of the container innage [7, 8].

Air chamber. Air chamber, (figure 3) is one of the types of popular equalization tanks. This device allows to smooth waves of high and low pressure, appearing in the pipeline in transitional processes. Also, air chamber allows transducing high-frequency vibrations in short pipes to low-frequency vibrations with small pressure amplitudes [9].

In general, air chamber is closed content, part of which is filled with pumped fluid, and other space with pressurized gas. Gas can be in free contact with liquid or separated with flexible divider.

Let's consider the principle of operation of the air chamber as an example of the transitional process, evoked by start up/shut-down of the pumping station. With start-up of pumping station, pressure on its outlet is increased fast and down the flow high pressure wave is distributed. For smoothing of such a wave, air chamber is installed on outlet of the station.

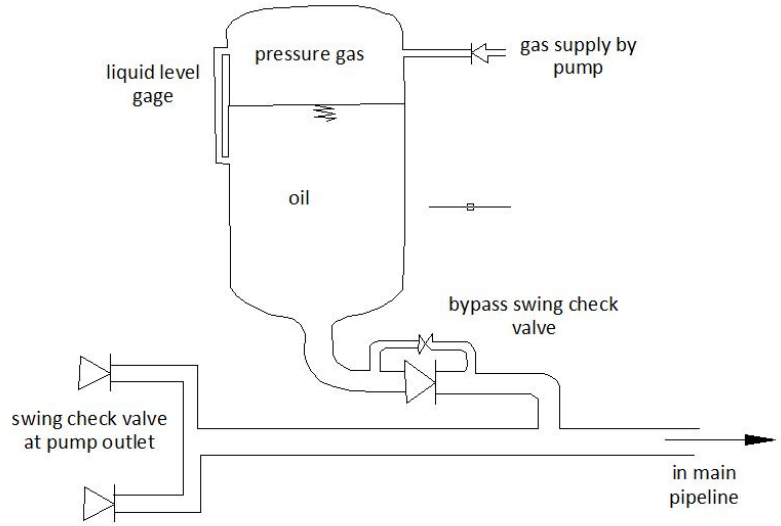

Figure 3 – Air chamber on outlet of the pumping station

After start-up of pump units, leakage consumption in the pipeline is increased, herewith part of the leakage starts to arrive at the air chamber, and the other part to the basic pipeline. As soon as it is filled up, gas into it is pressurized and pressure is increased, as a result, the pressure in the pipeline is increased to the relevant volume. Depending on size of the air chamber, for pressurization of gas, it is required to pump into the chamber different quantity of liquid. With relevant sizes of the air chamber, we can get the gradual increase of pressure on outlet of the Pumping Station with its start up.

With shut-down of the Pumping Station, it is observed the backward situation – pressure in inlet station is increased fast and up to the flow, high pressure wave is distributed.

Herewith, braking of flow is performed, id. est decrease of the pumping consumption. For protection of the pipeline from such pressure wave, air chamber is installed on entrance of the station. After shut-down of the pumping station, liquid is braked not immediately, it starts to enter the air chamber, thus gas pressure is increased. As the pressure in the chamber is increased, liquid is braked more and more up to the full shut down. Thus, air chamber of the relevant volume can smooth the appearing pressure wave on entrance of the Pumping Station with shut down.

However, air chambers have a significant defect. For smoothing of the pressure waves in trunk pipelines, volume of the air chamber shall compound no less than 100 m^5, which with accounting of the sufficient high pressure into the chamber, makes its using difficult in trunk pipelines. Effective using of air chambers is possible on short pipes of small diameter. In such cases, the necessary volume of air chamber compounds several cubic meters.

Pressure automatic control system (PACS). Maximum pressure on outlet of the pumping station is determined with carrying capacity of the pipeline, following after this station, and the minimum pressure on entrance – positive suction head of pump units, installed on the station. In transitional processes, in the pipeline, pressure in the inlet and outlet of Pumping Station can get out of the specified ranges. For purpose of avoiding this dangerous occurrence, system of automated pressure control is foreseen at the station. Pressure control on pumping station can implemented with following methods: throttling of flow; bypass of the flow part from discharge line to suction line of the station; amendment of rotation frequency of pumping units [10, 11].

Throttling of flow with purposes of pressure regulation is implemented by control valves, which are installed on discharge line of pumping station. Throttling of the liquid flow in the control valve of Butterfly type is shown in figure 4.

There is a cover of valve with increase of pressure on outlet of the pumping station higher than maximum or decrease of pressure on inlet lower than minimum, thus, the artificial local resistance is created. It leads to that the leakage consumption through the Pumping Station is decreased, pressure on entrance of station is decreased. Fast effect of control valves on trunk pipelines compounds 20–40 sec.

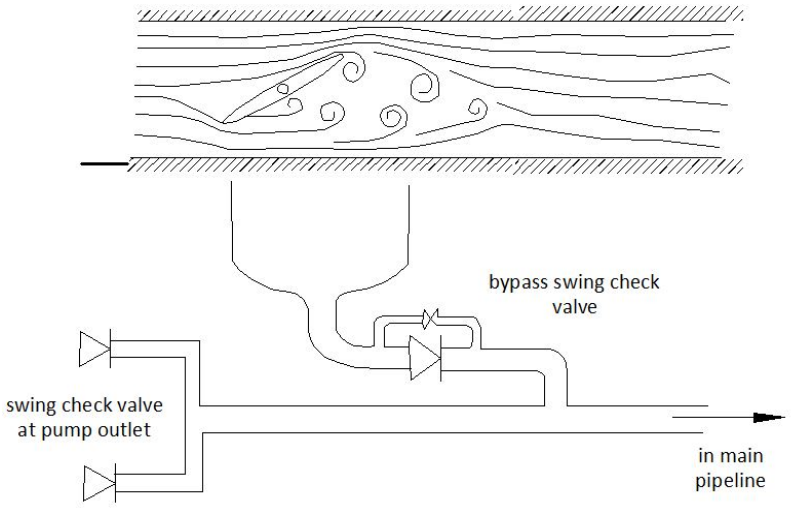

Figure 4 – Throttling of liquid flow in control valve of Butterfly type

Basic defect of such a regulation method is high losses of capacities during transitional processes, with which the necessity of throttling creates, as well as the inertance of control valves.

Amendment of rotation frequency of pumping units can be implemented by power actuator with regulating rotation frequency or installation of hydraulic coupling on shaft between the electric motor and pump. Decrease of rotation frequency of pump units leads to decrease of the differential head, created by the pumping station, that is why, pressure on inlet of the station is increased, and on outlet – is decreased. Advantage of this method is low losses of capacity; high fast effect.

With bypass, part of the liquid from discharge line is returned on special bypass to the suction line. Partial bypass of liquid can be implemented on one unit or through the whole pumping station. Taking into account downward characteristics of centrifugal pumping units, during the oil bypass through the pump, differential head, created by pumping station is decreased, that is why, pressure on inlet of the station is increased, and on outlet is decreased [12].

Pressure surge relief system. For pressure surge relief, created on inlet of pumping station with its shut down, it is used pressure surge relief system [13, 14]. Principle scheme of the pressure surge relief system is shown in figure 5. Pressure wave smoothing is implemented by partial discharge of oil from pipeline through the pressure surge relief system *4* to the container *5*. As distinct from safety valves, pressure surge relief system reacts if not to absolute volume of pressure, than to speed of its amendment. It is provided by control system of the pressure surge relief system, which compounds of orifice valve *2* and hydro pneumatic accumulator *3*. Pressure surge relief system does not restrict the pressure on inlet of pumping station on the certain level, pressure is continuously increased, but with lower adjusted speed.

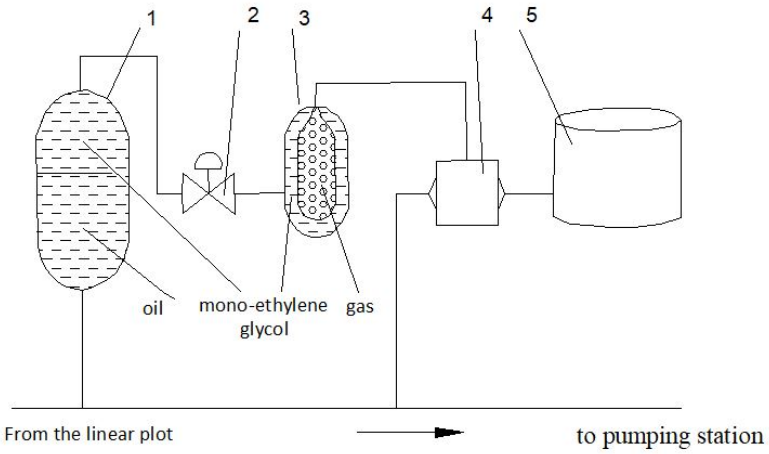

Figure 5 – Principle scheme of operation of the pressure surge relief system

Pressure surge relief system, installed on trunk pipelines, provides the average speed of pressure growth on inlet of pumping station with its termination 0.01–0.03 MPa/sec. For purpose of increase of reliability of the pressure surge relief system with its working liquid is in general ethylene glycol, which gets to the system through the dividing capacity *1*. Installation of necessary pressure growth speed on inlet of the pumping station is implanted by orifice valve and hydro-pneumatic accumulator. Pressure surge relief system 5.

One of the basic advantages of pressure surge relief system is its independence from power supply. Oil discharge volume through the pressure surge relief system valve with its operating on trunk pipelines compounds 30–100 m [15-17].

Fast-response valves with adjustable drive. Also, for smoothing of the pressure waves, appearing on inlet of pumping station, with its termination, fast-response valve with adjustable drive can be used. With shut down of pumping station, such a valve opens fast, and then closes slowly. Such property of valve operation is provided by "smart" drive, operation of which is implemented on special algorithm.

Specified system is similar with pressure surge relief system, however its basic defect is dependence on source of the power energy, whereas frequently the basic reason of emergency shut-down of pumping station is disruption in supply of the power energy. Of course, in such cases, this system does not operate [18, 19].

Results. For decrease of hydraulic loads and protection of oil pumping station equipment from negative influence of pressure waves, as power fluctuations, resistance moment, hydro dynamic moment and leading to possible loss of working capacity of the basic equipment, fast wear out and unjustified expenditures in Kazakh National Research and Technical University, risks control system was developed during transportation through the main pipeline.

The system is assigned for control and management of transportation mode with the purpose of prevention or minimization of risks situation consequences and supposes:

– prevention of passing of high pressure wave to operation zone of oil pumping station on timely operation of discharge valves;

– possibility of regulation of quantity and direction of coming and leaving leakage in ring shaped pressure surge relief system by discharge valves on adjusted algorithm depending on amplitude of form and wave period of the impact pressure. It means that system has in its compound pressure ring pipe waves smoother, operating based on the energy dissipation by counter flows and connected with main pipeline on discharge line of oil pumping station by means of two discharge valves.

Fast-response valves with pneumatic and power drive are controlled by automated control system, consisting of several boards. Differentiating unit on time allows to determine size of consumption jump, comparison unit detects difference of consumption in two points of the pipeline, delay unit on time serves for timely opening of the valve in time of wave coming to its section, regulation unit provides necessary volume of opening of valve and smooth close on the adjusted algorithm. Pressure regulation unit of the air smoother. Basic system of risks management is protection method of oil pumping station equipment from pressure waves, operation scheme of which is shown on the drawing 6.

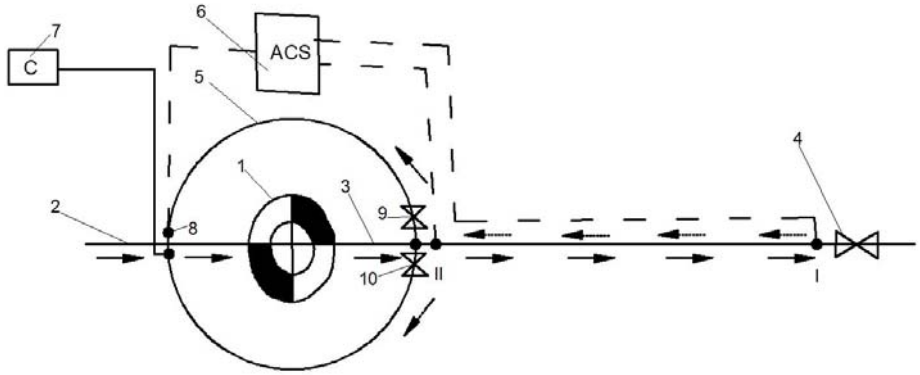

Figure 6 – Scheme of protection system from the pressure waves: 1 – pump station; 2 – station supply line; 3 – station discharge line; 4 – fastener on linear part of the pipeline; 5 – ring smoother; 6 – automated control system; 7 – compressor; 8 – pressure sensor; 9, 10 – smoother valves; I, II – flow meters

Waves smoothing is implemented in three modes, depending on amplitude of length of the form front and wave period, which is conditionally divided to 3 level. Value of parameters, in accordance with each level is entered to the program of control system. In the installed flow condition, when the consumption in point 1 equals to consumption in point 2, both smooth valves are closed during appearance of the high pressure wave (for example, in the result of close of the fastener 4) low consumption wave appears, which with pressure wave is distributed in the direction of pump station. When the wave achieves the section I, it is registered by the flow meter, signal of which is received to the control system. Automated control system determines the level of wave and by the adjusted delay, determined by the pressure wave speed gives the signal for opening until the first level of wave parameter of two smoothing valves. Oil from the main pipeline, under the effect of shock pressure intensively fills the smoother with two flows, moving towards each other. Herewith, pressing with liquid flow of the air, in the ring pipe of smoother is performed while the pressure in the air lock will not be equal to the pressure, discharged by the liquid shock wave. Air pressure of smoothers is controlled by pressure sensor, signal of which receives to the control system, if necessary, Automated Control System switches on the Compressor for increase of the pressure.

Process of the air pressing because of the transience can be deemed adiabatic [20]:

$$P_0 V_0^{\gamma} = P_{сж} V_{сж}^{\gamma}, \tag{1}$$

where P_0, V_0 is initial pressure and volume; $P_{сж}, V_{сж}$ – pressure and volume with air compression in the smoother.

Relevantly, work fulfilled by liquid flow with gas loading is equal to:

$$A = \frac{P_0 V_0}{\gamma - 1}\left[1 - \left(\frac{V_0}{V_{сж}}\right)^{\gamma - 1}\right]; \tag{2}$$

$$\text{or } A = \frac{P_0 V_0}{\gamma - 1}\left[1 - \left(\frac{P_{сж}}{P_0}\right)^{\frac{\gamma - 1}{\gamma}}\right]. \tag{3}$$

Protection of the equipment from negative influence of shock wave in the developed method is conditioned by decrease of wave energy before working zone by the managed discharge of part of the liquid flow to the smoother. During the passing of section by the low pressure wave discharge, air lock presses the oil from the smoother to the trunk pipeline, by increasing the pressure in the flow. By equalization of pressure in the flow and air lock, oil discharge from the smoother is terminated. Thus, the device can smooth the pressure pulsation in self- regulation mode of the oil emission/discharge process from the smoother to oil pipeline and conversely.

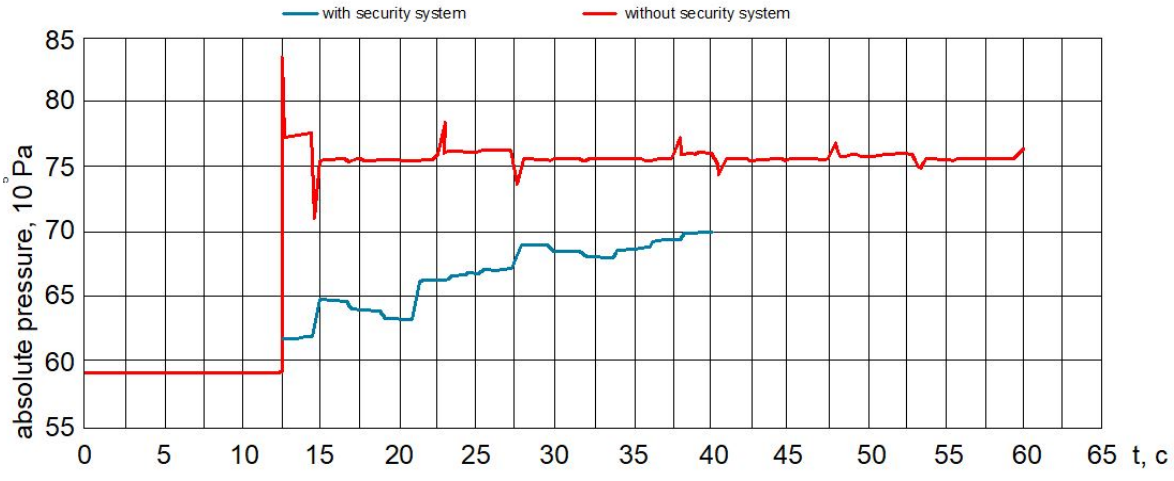

Figure 7 – Measurement charts of the pressure amendment in the section after the pump station

Control system during recovery of the flow stationary mode, by following the signals closes valves.

Using in researches of imitation of hydraulic stroke on section of the trunk pipeline allowed to increase work efficiency of the protection system in the result of prediction of development phase of the pressure wave, selection of optimum configuration and sizes of active part of the smoother, determination of flow parameters and their value for the sustainable management.

Effect from proposed protection system is specified on the drawing 7, from which is shown that average speed of the pressure increase, supported by the system does not exceed the permissible volume, specified in the process regulation as 0.03 MPa/sec.

Conclusion. Developed system fulfills all necessary functions on control and management of transportation modes with the purpose of prevention or minimization of hazardous situations consequence, which provides:

– prevention of passing of high pressure wave to operation zone of oil pumping station by the timely discharge vales,

– regulation of quantity, speed, and direction of coming – leaving leakage by discharge valves o the adjusted algorithm,

– possibility of the system to operate in several modes of smoothing, including the self-regulation mode of emission-discharge processes, for provision of reliable protection with different values of the pressure waves.

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МҰНАЙ АЙДАУ СТАНЦИЯЛАРЫНЫҢ ЖАБДЫҒЫН ГИДРАВЛИКАЛЫҚ ЖҮКТЕМЕЛЕРДЕН ҚОРҒАУ ЖҮЙЕСІ

Аннотация. Жұмыста мұнай айдау станциясының жабдықтарын жоғары қысым толқынынан қорғайтын әдістер мен құрылғылардың және қолданыстағы жүйелердің талдауы жүргізілген. Негізгі жүйе ретінде гидравликалық жүктемелерден қорғау үшін төмен қысымды құбыр жүйелерінде кеңінен қолданылатын теңестіруші резервуарлар қарастырылған. Ауа қалпағы қысымның жоғары жиілікті тербелістерін кішірейген амплитудағы төмен жиілікті қысымға түрлендіру арқылы әртүрлі қысымдағы толқындарды тегістеуге мүмкіндік береді. Автоматты реттеу жүйесі реттегіш жапқыштардың құралдары және т.б. бойынша ағысты шектеу арқылы қысым толқындарын тегістеуді жүзеге асырады. Гидравликалық жүктемелерге қарсы күрес бойынша бірқатар артықшылықтарға қарамастан, олар мұнайды тасымалдаудың технологиялық режимдеріне байланысты бірқатар елеулі кемшіліктерге ие. Осы кемшіліктерді жою үшін қысымның пульсациясын қарсы ағында тегістеу тәсіліне негізделген жаңа қорғаныс жүйесі ұсынылады. Жүйе қолдайтын қысым өсуінің орташа жылдамдығы технологиялық регламентте көрсетілген 0,03 Мпа/с шамасынан аспайды. Жүйе жоғары қысым толқындарының әр түрлі қарқындылығы кезінде сенімді қорғауды қамтамасыз ету үшін бірнеше тегістеу режимдерінде жұмыс істей алады және лақтыру-шығару процестерімен өзін-өзі реттеу режимін қамтиды. Жүйенің тиімділігі автоматты басқару жүйесімен қамтылады.

Түйін сөздер: мұнай құбыры, айдау станциясы, гидравликалық жүктемелер, пульсацияны тегістеу, қысым толқындары, ауа қалпағы, теңестіргіш резервуар, жапқыш, клапан.

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СИСТЕМА ЗАЩИТЫ ОБОРУДОВАНИЯ НЕФТЕПЕРЕКАЧИВАЮЩИХ СТАНЦИЙ ОТ ГИДРАВЛИЧЕСКИХ НАГРУЗОК

Аннотация. В работе проведен анализ существующих систем, методов и устройств по защите оборудования нефтеперекачивающей станции от волн повышенного давления. В качестве основных систем рассмотрены уравнительные резервуары, которые широко используются в трубопроводных системах низкого давления для защиты от гидравлических нагрузок. Воздушный колпак позволяет сглаживать волны различного давления за счет преобразования высокочастотных колебаний давления в низкочастотные с пониженной амплитудой. Система автоматического регулирования, осуществляющая сглаживание волн давления дросселированием потока по средствам регулирующих заслонок и т. д. Несмотря на ряд достоинств по борьбе с гидравлическими нагрузками они имеют ряд существенных недостатков, связанные с технологическими режимами транспортирования нефти. Для их устранения предлагается система защиты, в основе которой

лежит способ по сглаживанию пульсации давления на встречных потоках. Средняя скорость роста давления, поддерживаемая системой не превышает допустимой, указанной в технологическом регламенте величины 0,03 МПа/с. Система может работать в нескольких режимах сглаживания для обеспечения надежной защиты при различной интенсивности волн повышенного давления и включает режим саморегулирования процессами выброса-сброса. Эффективность системы поддерживается автоматической системы управления.

Ключевые слова: нефтепровод, перекачивающая станция, гидравлические нагрузки, сглаживание пульсаций, волны давления, воздушный колпак, уравнительный резервуар, заслонки, клапан.

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REFERENCES

[1] Kabylbekov K.A., Dasibekov A.D., Abdrakhmanova Kh.K., Saidakhmetov P.A., Issayev E.B., Urmashev B.A. Calculation and visualization of oscillatingsystems // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. Scopus ISSN: 2224-5278. 2018. Vol. 6, N 432. P. 110-119 (in Eng.). https://doi.org/10.32014/2018.2518-170X.41

[2] Isametova M.E., Absadykov B.N., Batyrgaliyev M.K., Borovik I.I. Centrifugal pump rotor dynamics study // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technical sciences. Scopus ISSN: 2224-5278. 2018. Vol. 5, N 431. P. 226-233 (in Eng.) https://doi.org/10.32014/2018.2518-170X.29

[3] Kabylbekov K.A., Abdrakhmanova Kh.K., Omashova G.Sh., Lakhanova K.M., Abekova Zh.A. Organization of computer laboratory work “calculation and visualization of small forced oscillations” // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. Scopus ISSN: 2224-5278. 2018. Vol. 3, N 430. P. 145-154 (in Eng.).

[4] Korshak A.A., Nechval' A.M. Proektirovanie i jekspluatacija gazonefteprovodov / Rostov n-D: Feniks, 2016. - 516 s.

[5] Adoevskij A.V. O vozmozhnom avarijnom otkljuchenii perekachivajushhej stancii pri zapuske i ostanovke nasosnogo agregata // Neftjanoe hozjajstvo. 2010. N 10.

[6] Adoevskij A.V. Ustojchivost' k otkljucheniju promezhutochnoj PS pri sbrose nefti na linejnom uchastke // Izv. Vuzov. Neft' i gaz. 2009. N 5.

[7] Stanev V.S., Gumerov A.G., Rahmatullin Sh.I. Issledovanie antikavitacionnoj ustojchivosti gidravlicheskoj sistemy pri gidroudare v truboprovode // «Neftjanoe hozjajstvo. 2004. N 5.

[8] Lur'e M.V., Poljanskaja L.V. Ob odnom opasnom istochnike voln gidravlicheskogo udara v nefteprovodah // Neftjanoe hozjajstvo. 2000. N 8.

[9] Poljanskaja L.V. Sistema iz dvuh vozdushnyh kolpakov kak sredstvo umen'shenija krutizny volny davlenija v truboprovode // Izv. vuzov. Neft' i gaz. 1969. N 4. P. 90-94.

[10] Vladimirskij A.I., Drongovskij Ju.M., Zajcev L.A., Livanov Ju.V. Avtomatizacija i telemehanizacija magistral'nyh nefteprovodov. M.: Nedra, 1976. 222 p.

[11] Kruisbrink A.C.H. Modelling of safety and relief valves in water-hammer computer codes // Procs. 3rd. Inti. Conf. on Developments in Valves and Actuators for Fluid Control, Bournemouth, Spons. British Hydromechanics Research Association, Cranfield, Beds. 1990 (in Eng.)

[12] Lur'e M.V. Matematicheskoe modelirovanie processov truboprovodnogo transporta nefti, nefteproduktov i gaza. M.: «Neft' i gaz» RGU nefti i gaza im. I. M. Gubkina, 2003. 335 p.

[13] Adoevskij A.V. SSVD kak sredstvo zashhity magistral'nyh nefteprovodov ot voln povyshennogo davlenija // Promyshlennaja bezopasnost' i jekologija. 2010. N 8.

[14] Adoevskij A.V., Arbuzov N.S., Levchenko E.L., Lur'e M.V. Zashhita nefteprovodov ot gidroudarnyh javlenij sistemami sglazhivanija voln davlenija // Neftjanoe hozjajstvo. 2010. N 12.

[15] Verushin A.Ju., Rahmatullin Sh.I., Zaharov N.P. O raschete gidroudara pri zakrytii sharovogo zatvora v promezhutke vremeni, bol'shem prodolzhitel'nosti fazy // Neftjanoe hozjajstvo. 2010. N 3.

[16] Levchenko E.L., Nikolaev S.B, Bekker L.M. K voprosu o primenenii sistem sglazhivanija voln davlenija na nefteprovodah AK «Transneft'» // Truboprovodnyj transport nefti. 2001. N 12. P. 19-27.

[17] Lur'e M.V., Adoevskij A.V. Modelirovanie i predvaritel'naja nastrojka sistem sglazhivanija voln davlenija // Izv. Vuzov. Neft' i gaz. 2009. N 6.

[18] Stanev V.S., Rahmatullin Sh.I. Uchet zatuhanija gidroudara v magistral'nom truboprovode // Neftjanoe hozjajstvo. 2003. N 9.

[19] Stanev V.S., Gumerov A.G., Gumerov K.M., Rahmatullin Sh.I. Ocenka prochnosti uchastka magistral'nogo truboprovoda s uchetom gidroudara // Neftjanoe hozjajstvo. 2004. N 4. P. 112-114.

[20] Barkov Ju.A., Votnikov G.N., Zverev O.M., Perminov A.V. Kratkij kurs obshhej fiziki: Ucheb. posobie. Izd-vo Perm. nac. issled. politehn. un-ta, 2015. 407 p.

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MULTI-FUEL POWER STATION OF ULTRA-LOW POWER WITH EXTERNAL COMBUSTION THERMAL ENGINE, CAPABLE EFFICIENTLY OPERATE IN THE CONDITIONS OF RURAL AREAS OF KAZAKHSTAN

Abstract. The problem of effective electric supply is not solved in full until now. One way to solve this problem is development a micro thermal power plant, that capable operate on virtually any fuel. The use of own energy source will allow to reduce its development cost. Significantly increase the reliability of electricity supply and ensure its uninterrupted supply to the consumer. The proposed by us power plant is driven by a heat engine with an external heat supply. Some results of computer simulation of an engine with an external heat supply, which works according to the Stirling principle, are given. The design features of the engine under development are considered.

Conducted research allows us to find the optimal parameters of the structural parts of the heat engine. Accurately establish the geometrical dimensions of the piston and displacer, as well as the magnitude of their stroke with the optimum value of the phase shift.

Keywords: thermal power plant, Stirling engine, cogeneration, thermal energy, integrated production, alternative energy.

The general part and a preliminary analysis of the development level of the engine with external heat supply. The Stirling engine (SE), proposed as an alternative to the steam engine at the beginning of the nineteenth century, has undergone many stages of development and transformation, and now arouses sufficient interest among inventors. New SE designs are being created and new technologies are being used to create them. Today several models can serious compete with internal combustion engines (ICE), for example, by technical and environmental indicators. Despite all achievements and advantages they still did not find wide application as electric machines or internal combustion engines, but there are a number of serious reasons for this. Working fluid (gas or liquid) moves in enclosed volume in a cycle of the periodic heating and cooling of the working fluid. For its work suitable particular any fuel or heat source [1]. Thereby this unique of its kind thermal engine has high efficient equal a maximum effective of thermal engines, but in reality, in practice it is extremely difficult to achieve.

In historical terms, heat engine offered and patented in 1816 (English patent № 4081) by catholic priest Robert Stirling, served as a push in the development of this direction. Heat engines, which use heated air in their work, were already used in the 17th century, he only improved the design and suggested using a regenerator, which he called "economy". Modernization allows reducing weight and achieving an efficiency about 10%. This nod allowed increasing efficiency and created competition for the steam engine, it gave opportunity to introduce them at a number of enterprises. First of all, it was safe in terms of allowing an explosion, which was not uncommon for steam engines of that time. His engine was made from cast iron weighing one ton and produced 1kW, at that time, it could provide decent competition to a steam engine [2]. The lack of wear-resistant seals and heat-resistant steels did not allow Stirling to achieve

success in efficiency, and the rapid development of ICE and electric motors in the early 20th century completely drove them out of the market, but with the development of technologies and materials, engineers in 50-60 years of the last century again showed interest in them. The development of new SE designs continues to this day. For example, the Philips company, which produced compact electric generators based on an engine with an external heat supply operating on the Stirling cycle with an efficiency of about 30%, achieved particular success, which is not yet achievable for most modern gasoline power plants with ICE [3]. New machines had higher efficiency by increasing the pressure in the working cavity (in cylinders and chambers), which significantly improved the indicator "weight / size / power".

Our review showed that more than two centuries of history of the development they have gone through several stages of transformation and significant structural changes that have increased their efficiency. Today, engineers from various countries around the world have created dozens of designs of heat engines with an external heat supply (EEHS), working on the Stirling cycle. It would be more correct to say that these heat engines combine only a number of essential features related to external heat supply and the Stirling thermal cycle. Stirling himself is not the author of all development. On the contrary, his heat engine was largely imperfect, what he himself wrote about, and modern engines with external heat supply in some structures have nothing to do with the proposed invention. In the scientific literature, completely different in design EEHS, about which there was no speech in his works, are attributed to the authorship of Stirling.

There are main types of Stirling heat engines: alpha, beta and gamma, but more promising at present for use in the energy sector are free-piston and thermo-acoustic machines, because they have higher efficiency and better indicators of weight and dimensions per unit of power [4]. Stirling engine used in cases when a small heat energy converter is needed, simple in design, or when the efficiency of other heat engines is lower, for example if the temperature differences is not sufficient for the operation of a steam or gas turbine.

Stirling engine can be used to convert thermal energy into mechanic and then into electric. On them pin hopes on the creation of solar electrical installations. They are used as stand-alone generators for tourists. Some companies produce generators, which are powered by gas burners.

There are several advantages of using the EEHS for a multi-fuel micro power plant:

1. multi-fuel capability and ability to work on a locally available fuel;
2. considerable service life of 20,000 hours;
3. the possibility of cogeneration of heat and integrated energy production;
4. from 3 to 6 times lower cost generated kW power;
5. full autonomy and independence from the rates and market conditions of the oil and natural gas market;
6. high environmental performance of Euro – 5 and higher, that meets the most stringent international environmental standards;
7. the payback period of cogeneration plants is 2-4 years;
8. no need for laying and maintenance of electrical grids in the electrification of remote areas;
9. a significant reduction in the cost of regional budgets for the purchase of imported fuel.

In a different time, a number of foreign companies were very active in researching and developing new designs of SE or an engine with an external heat supply, for example, “Philips” (Netherlands), “General Motors Co”, “Ford Motor Co.”, “NASA Lewis Research Center”, “Los Alamos National Laboratory” (USA), “ MAN-MBW ”(Germany), “ Mitsubishi Electric Corp.”, “Toshiba Corp. ”(Japan). During the last decade, work on the creation of Stirling engines also began in the “Daimler Benz” and “Cummins Power Generation” (CPG) [5]. In a different time, many research and practical experiments have been carried out on the use of the Stirling engine for various needs, including the power generation [6]. At present, several large companies engaged in the development of cogeneration-type power plants are active in Russia, for example, LLC Information Technology Company “Stirling-Technology”. The market has products manufactured by OJSC Machine-Building Plant Arsenal, SPO Geliymash, etc. The EEHS manufactured by these enterprises are not Russian developments, but are copies of cryogenic machines previously produced by the Dutch firms NV Philips Gloeilampenfabrieken (Phillips) and “Werkspoor”. In Russia, due to the economic crisis, an extremely unfavorable innovative atmosphere and scientific organizations have emerged, in which work on the creation of new EEHS, for example, Bauman MSTU, ARSRIHT, OSTU,

St. Petersburg State Technical University (Polytechnic University), CRDRI were forced to close their programs due to financial difficulties. At the same time, in the countries of the European Union, the United States and Japan over the past 15 years, positive results have been achieved in the creation of high-performance Stirling machines, for example, of a thermoacoustic type with linear generators. In the beginning of 21-th century, a number of experimental researches were made by experts of LLC IRC Stirling technology, as a result of which a new methodology was developed for designing and calculating machines of this cycle. This methodology includes some know-hows among them: a unique method of two-level multiparameter optimization of Stirling engines; structural synthesis of Stirling machines based on the method of functional-exergy analysis of complex heat-mechanical devices and optimal design. Based on offered technical decisions, in 1994-2003 years more than 150 applications for alleged inventions have been filed by experts of LLC IRC Stirling technology. Particular attention was paid to the elaboration of individual units of Stirling machines and their design, an also the creation of new schematic diagrams of installations of various functional purposes. Practice has shown that optimal design will significantly reduce the total unit cost of machines with their pilot and mass production. The proposed technical solutions, taking into account the fact that Stirling machines are less expensive to operate, make it possible to increase their economic profitability in comparison with traditional energy converters. Further widespread Stirling machines will be associated with the development of the theory of designing multi-cylinder machines of this cycle, what will allow to create engines and refrigerators with a productivity up to 1000 kW.

Some problems associated with the creation of high-performance Stirling machines. Analyzed by us foreign experience in creating of high-performance the EEHS and Stirling engines showed that without accurate mathematic simulation of working processes and optimal designing of main knots the tweaking of projected machines is turning into long-term, exhausting, investigational study with low probability of successful result. The leading developments of companies in the European Union, the USA and Japan are based on the theoretical and experimental studies of their scientists from universities and technological park who are engaged in the development of certain types of Stirling machines. There are not fully solved technical problems related to the design of individual components, especially seals, power control, etc. There are problems caused by the use of various working fluids, such as low efficiency of air during heating and prevention of leakage of hydrogen, which is the most efficient working fluid. There are constructions using helium as a working fluid; it is much more efficient than air, but it has superfluidity which places increased demands on the sealing elements of the working piston of the propellant rod, etc., and this affects the cost of manufacturing of the EEHS. In contradistinction to ICE, the seals work in the dry friction mode, because the lubricant can severely contaminate the working fluid and adversely affect the operation of the EEHS, therefore the seals should have a low friction coefficient and high wear resistance. Work continues on the design of promising and new FEPT structures, which are being introduced into production, for example, free-piston, which do not have the drawbacks of classic EEHSs. To achieve high efficiency a high level of production technology and quality of materials is required, and this increases their cost, making them not available for mass general use. For example, WhisperGen company (New Zealand) has developed for the European market a microthermal power plant of a cogeneration type with an external combustion heat engine (Stirling engine), costing about 8 thousand euros, but if we consider its delivery to Kazakhstan, the price will increase by at least 50%. This unit is able to generate complex electrical power - 1 kW and heat - 5.5 kW, that may be enough for a small rural house. This technique is not available to the villager because of the high cost and the lack of natural gas for its work, this makes it unclaimed in the countryside. High cost generated by the need to use heat-resistant alloys and non-ferrous metals, welding and soldering. Considerable funds are invested in the manufacture of the regenerator and the nozzle for it, because it is necessary on the one hand high heat capacity, and on the other hand, low hydraulic resistance. Production requires high-tech equipment and highly skilled workers, and this also significantly increases the cost. High technology intensity and manufacturability of production, and also use of expensive materials is the main deterrent to the wide distribution of modern EEHS. For the creation of competitively manufactured EEHS on the world market, it can be achieved only as a result of synthesis of advanced scientific research and high professional constructive study of the main components, and also advanced production technology.

Development of a multi-fuel power plant of ultra-low power with a heat engine of external combustion. The aim of our scientific work is the development of the engine with external heat supply for micro electric multi-fuel capable operating effectively in rural areas of Kazakhstan.

We set our future task to develop a series of micro power plants with a capacity from 1 to 100 kW based on a free-piston external combustion engine and a linear generator for powering rural residents of Kazakhstan. Our work was performed in the framework of the project "Micro thermal power plant of coherence type with heat recovery" (No. AP05131751).

This type of heat engine was invented in the 50s of the last century by "Sunpower" company in the USA. Design turned so successful from the entire Stirling family that NASA engineers developed several options for their use on spacecraft. German engineers have made a number of developments for their use in everyday life; it can work as a generator, pump and thermocompressor [7].

Earlier, a number of recommendations were formulated on the use of the Stirling engine for energy supply to rural consumers, and also gave the main results of the research [8].

The compact cogeneration power plant is capable producing electrical and thermal energy, at a ratio of 1/5 kW, with an efficiency of 10-20% and 40-50%, respectively, by types of energy. In the future, carrying out work to improve and optimize the design parameters to achieve the integrated efficiency about 90%. This unit will produce heat energy about 5 times more than electric energy, because the heat energy of the cooling water and exhaust gases is used for the needs of the consumers' heat supply.

The effectiveness of the Stirling engine in cogeneration plants, compared to ICE, caused by feature of its heat balance. Figure 1 shows the layout of a multi-fuel micro-power station with a power of 1 kW with an engine with an external heat supply, in three possible variants, based on the use of the energy-saving Tandyr effect. This unit produces 1 kW/h of electrical energy and 5-6 kW/h of heat, which is more fully sufficient for a small rural house. The cooling circuit operates in the summer, and in the cold season it is replaced by the heating system of a residential house. The unit operates on the accumulation of electrical and thermal energy. Aggregators allow you to achieve stability in its work and provide maximum load

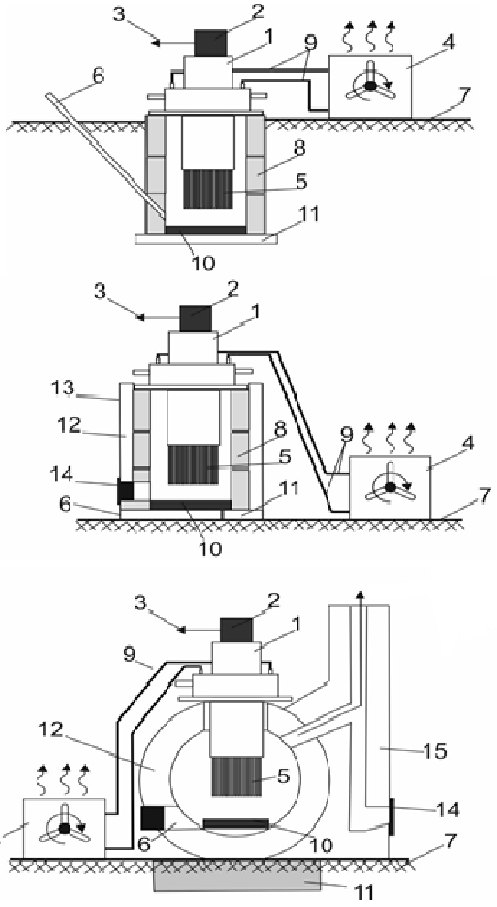

Figure 1 – Possible options for the layout of a multi-fuel power plant with a power of 1 kW with an engine with an external heat supply

peaks, and also to balance the volumes of energy produced and consumed with minimal losses. The unit is mounted in a furnace or “Tandyr” which is preliminarily pre-fired. The unit can also operate in a continuous mode while maintaining the process of burning the fuel.

The installation consists of: free-piston engine of external combustion 1; linear AC generator of permanent magnet 2 and cable line 3 with a voltage of 220 V. The cable connects to an AC220 / DC24V converter, for charging a battery with a capacity of approximately 200 A/h; cooling system (heating) 4, the more efficiently it works, the higher the efficiency of entire installation; working fluid heater 5 made of stainless heat-resistant steel; air supply system 6; the foundation of the earth is 7; brickwork of refractory bricks 8; pipeline for cooling system 9; fire grate 10; concrete base of the furnace 11; heat insulation 12; lining 13; cleaning hatch 14; chimney to remove combustion products 15.

Installation works in the following way, under the action of high temperature from 300 to 7000 power unit based on a free piston external combustion engine 1 drives the linear ac generator on permanent magnet 2, the generated current through the cable line 3 with a voltage of 220 V is fed to an AC-DC converter AC220 / DC24V which has a charge controller and charges the batteries with a minimum capacity of 200 A/h, it is desirable to increase the battery capacity by 2-3 times to eliminate the shortage of electricity and Avoid emergency shutdown of the autonomous system when the battery is low. If there are several powerful receivers in the house, then it is necessary to separately calculate the capacity necessary for their work. Direct current can be directly delivered to consumers, such as LED electric lamps, and partially inverted to drive the refrigerator and washing machine. The important point of the effective operation of the installation is the cooling (heating) system 4, the more efficiently it works, the higher the efficiency of the entire installation, therefore it is better to cool the working fluid than to increase the temperature of the heater. The cooling system is connected through pipelines 9 and is divided into direct and reverse; automobile antifreeze can be used as a coolant. An electric pump (pump) is used to circulate the coolant, and the house heating system is connected via a heat exchanger. For storage of excess heat energy is required tank with thermal insulation capacity of 200 - 500 liters.

The heater of the working fluid 5 directly senses the heat and must be made of heat-resistant steel, to increase efficiency, it is equipped with additional tubular heaters and an internal regenerator. To ensure the process of burning fuel furnace or "Tandyr" should be equipped with air supply 6. The important point is the design of the furnace itself, the main thing is its quality should be energy saving and heat preservation, that is why special attention is paid to thermal insulation.

Electric scheme of the unit is shown in figure 2, the basic idea is to divide the load into variable and constant. This will avoid unnecessary transformations and losses, because most modern household electrical equipment operates on direct current, for example, a laptop or a cell phone.

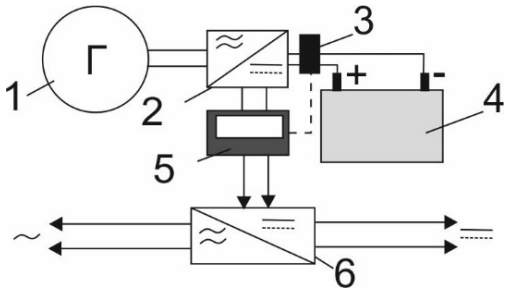

Figure 2 –Electric generation scheme

LED electric lamps can also operate on DC without a driver. AC is only needed for the refrigerator, washing machine, microwave, therefore, an inverter is provided for them. The system of generating electrical energy comprises a linear synchronous AC generator 1, made on permanent magnets, a semiconductor AC rectifier 2, battery charge controller with relays 3 and 5, battery 4, switchgear 6 for dividing the load into alternating current with power from the inverter and to direct current to supply the DC load directly from the battery.

To conduct research, we developed an experimental motor with an external heat supply, presented in figure 3, the power of an electric generator with permanent magnets is 100 watts.

Figure 3 – Experimental laboratory installation with a capacity of 100 W

Helium is used as a working fuel with the addition of a small percentage of water, which allows creating pressure up to 12 MPa.

We have carried out computer simulation of free piston engine, obtained results will help to create an optimal design with the highest possible efficiency. A number of dependencies, affecting the power associated with the temperature of the heater and cooler, diameter and stroke of pistons phase and other parameters installed.Separately, experiments allowing construct a Carnot closed thermal cycle diagram and consider the dependence of pressure and volume at different positions of the pistons have been carried out. The results are shown in figure 4.

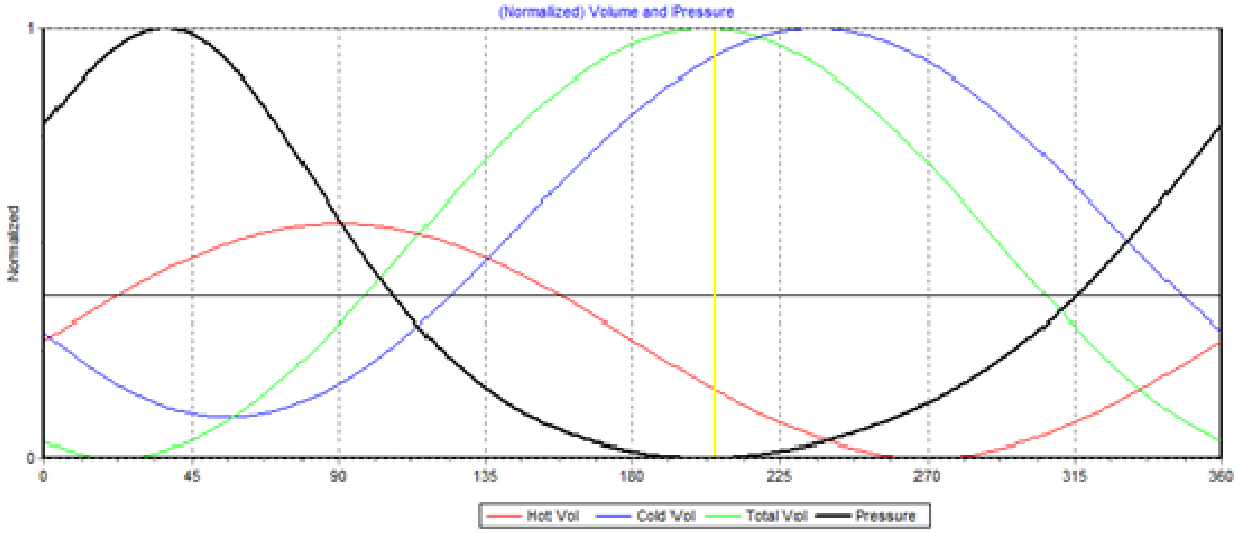

Figure 4 – Dependence of pressure and volume at different positions of the pistons

Conducted research allows us to find the optimal parameters of the structural parts of the heat engine, to establish the dimensions of the piston and the displacer, and also the magnitude of their stroke with the optimum phase shift value.

Conclusion. The use of an engine with external heat supply for a multi-fuel microelectric station capable of working effectively in rural Kazakhstan is very promising and requires a comprehensive scientific study. We believe that the most promising design of the drive of the power unit is a free piston engine with external heat supply.

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ҚАЗАҚСТАННЫҢ АУЫЛДЫ АЙМАҚТАРЫНДА ТИІМДІ ЖҰМЫС ЖАСАЙ АЛАТЫН СЫРТҚЫ ЖАНУ ЖЫЛУ ҚОЗҒАЛТҚЫШЫ БАР КӨПОТЫНДЫ АЗ ҚУАТТЫ ЭЛЕКТР СТАНЦИЯСЫ

Аннотация. Энергияны тиімді пайдалану мәселесі бүгінгі күнге дейін толық шешілмеген. Бұл мәселені шешудің бір жолы – кез келген жанармайда жұмыс істеуге қабілетті микро жылулық электр станциясын дамыту болып табылады. Энергияны өндіру үшін жергілікті аймақтағы әр түрлі отын түрлерін қолдану кететін қаражат көлемін азайтады. Электрмен қамтамасыз ету сенімділігі айтарлықтай артады және оны тұтынушыға үздіксіз жеткізу қамтамасыз етіледі. Ұсынылған электр станциясы сыртқы жылумен қамтамасыз ететін жылу қозғалтқышымен басқарылады. Стирлинг принципіне сәйкес жұмыс жасайтын сыртқы жылумен жабдықтаушы қозғалтқышты компьютерлік модельдеудің кейбір нәтижелері келтірілген. Жасалып жатқан қозғалтқыштың дизайн ерекшеліктері қарастырылған.

Жүргізілген зерттеулер жылу қозғалтқышының құрылымдық бөліктерінің оңтайлы параметрлерін табуға мүмкіндік береді.

Түйін сөздер: жылу электр станциясы, Стирлинг қозғалтқышы, когенерация, жылу энергиясы, комплексті өндіру, альтернативті энергетика.

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МНОГОТОПЛИВНАЯ ЭЛЕКТРОСТАНЦИЯ СВЕРХМАЛОЙ МОЩНОСТИ С ТЕПЛОВЫМ ДВИГАТЕЛЕМ ВНЕШНЕГО СГОРАНИЯ, СПОСОБНАЯ ЭФФЕКТИВНО РАБОТАТЬ В УСЛОВИЯХ СЕЛЬСКОЙ МЕСТНОСТИ КАЗАХСТАНА

Аннотация. Проблема эффективного электроснабжения не решена в полном объеме до сих пор. Одним из путей решения данной проблемы является разработка микро тепловой электростанции, способной функционировать практически на любом топливе. Использование собственного источника энергии позволит снизить затраты на ее производство. Существенно повышаются показатели надежности электроснабжения и обеспечивается ее бесперебойная поставка потребителю. Предложенная нами электростанция приводиться в действия тепловым двигателем с внешним подводом теплоты. Приведены некоторые результаты компьютерного моделирования двигателя с внешним подводом тепла, который работает по принципу Стирлинга. Рассмотрены конструктивные особенности разрабатываемого двигателя.

Проведенные исследования позволяют найти оптимальные параметры конструктивных частей теплового двигателя. Точно установить геометрические размеры поршня и вытеснителя, а также величину их хода с оптимальным значением фазового сдвига.

Ключевые слова: тепловая электростанция, двигатель Стирлинга, когенерация, тепловая энергия, комплексное производство, альтернативная энергетика.

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REFERENCES

[1] Bobylev A.V., Zenkin V.A. The mathematical model of Stirling's free-piston engine // Bulletin of Equipment. Technologies. Engineering. Ser. Power engineering. 2017. N 1. P. 22-27 (in Rus.).

[2] Verevkin M.G. Method of complex thermal and design calculation of a thermomechanical generator // Bulletin of Proceedings of higher educational institutions. Ser. Mechanical engineering. 2004. N 10. P. 33-37 (in Rus.).

[3] Afanas'ev V.A., Tseytlin A.M., Polyakov P.B., Gavlovich R.Yu. Estimation of the efficiency of the cryogenic Stirling engine, which is part of the gasifier of liquefied natural gas, the gas-powered system of the marine engine // Bulletin of vestnik of astrakhan state technical university. Ser. marine engineering and technologies. 2013. N 1. P. 78-83 (in Rus.).

[4] Gorozhankin S.A., Savenkov N.V., Chukharkin A.V. Combined gas turbine units with Stirling engines // Bulletin of The founder and publisher of the journal is the St. Petersburg State Polytechnical University. 2015. N 2(219). P. 57-66 (in Rus.).

[5] Mekhtiev A.D., Yugay V.V., Al'kina A.D., Kim P.M., Aldoshina O.V., Mekhtiev R.A., Balapanova D.D., Fedorova A.V. Mini CHP with a linear current generator with a recuperator for recycling waste combustible. Certificate of state registration of rights to the object of copyright of the Republic of Kazakhstan. N 0956. 23.05.2016 (in Rus.).

[6] Bulatbaev F.N., Yugay V.V., Al'kina A.D., Neshina E.G. Alternative heat-power plant cogeneration type mini-CHP. Certificate of state registration of rights to the object of copyright of the Republic of Kazakhstan. N 2385. 15.11.2016 (in Rus.).

[7] Zhaukeshov A.M. To the selection of components of a solar power station with a Stirling engine // Bulletin of herald of the Kazakh National University. Ser. Physical. 2014. N 4(51). P. 85-89 (in Rus.).

[8] Mekhtiyev A.D., Yurchenko A.V., Bulatbayev F.N., Neshina Y.G., Alkina A.D. Theoretical bases of increase of efficiency of restoration of the worn out hinged joints of mine hoisting machine // News of the academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 5, N 431. P. 66-75. https://doi.org/10.32014/2018.2518-170X ISSN 2518-170X (Online), ISSN 2224-5278 (Print).

[9] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[10] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[11] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[12] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[13] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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DEFORMATION FEATURES OF THE CENTRAL LAYERS OF Fe – 3%Si(110)[hkl] ALLOY BY ROLLING WITH A ROLL DIAMETER OF 90 MM

Abstract. The article presents the results of studies of the effect of initial crystallographic orientation and deformation modes on rolling texture in the central layer of *Fe – 3%Si(110)[hkl]* single crystals.Several groups of samples of single crystals were rolled under laboratory conditions. The groups of samples were classified according to the final deformation rate, the ideal crystallographic orientation of the rolling plane and deflections of the direction of the ideal orientation plane from the rolling direction. The methodology of the experiment took into account the amount of reduction rate during one rolling. Radiographic method was used to analyze the results of rolling. The obtained data was superimposed on a stereographic projection, and straight pole figures were built. The results of decoding direct pole figures revealed differences in the formation of the texture from the previously obtained results. The research shows the manifestation of the one-component deformation texture in the central layer.

Keywords: deformation of single crystals, crystallographic texture, standard crystallographic projection, pole figures, deformation texture**.**

Introduction. The studies of texturing of metals and alloys, as well as their influence on the final properties of semi-finished products and final products, are conducted by specialists of the machine-building complex and scientists from different fields. The examples of these fields are solid-state physics, physical metallurgy, plastic deformation, mathematics.

Nowadays, the main types of textures are represented by axial, conical and rolling textures, classified within the group according to the symmetry.

Theoretical and experimental data in the metal forming, based on the preferred orientation in microplastic deformations, allows us to design new types of textures using special schemes of the external field of influence, based on the symmetry approach.

The design of new types of textures, on a symmetry basis, is aimed at obtaining semi-finished products and products with predetermined physico-mechanical and special properties. As a result, it will lead to the improvement of the operational properties of machines and mechanisms, and increase both technical and economic indicators of the machine-building complex.

The formulation of the research problem and the physical essence of the process. The formation of texture during plastic deformation is a consequence of the rotation of crystallographic planes and directions relatively to technological or another special direction. The crystallographic texture, being the main component in the formation of physico-mechanical properties in polycrystalline materials, is determined by the initial texture of the workpiece before processing and its main kinematic and dynamic parameters. One of the ways to optimize the physico-mechanical properties of semi-finished and finished

products made of polycrystalline materials can be accomplished by controlling the texturing. The initial crystallographic orientation of the original workpiece must be taken into account.

Thus, the task of the current paper is to determine the effect of the initial *(110)[hkl]* texture of Fe–3%Si single crystals on the deformation texture in the central layers during rolling with different reduction rate.

The difference between rolling deformation of *(110)[hkl]* alloys on the surface and deformation of the central layers is that maximum stress axes rotate continuously around the transverse direction of rolling. As a result, there is a change in the slip systems involved in the deformation process. In case when the single crystal is oriented ideally relative to the (110) plane, there is a symmetric change of slip systems on the opposite surfaces. However, when this orientation is shifted towards the direction of rolling, there is an ambiguous participation of the slip systems in the deformation.

The influence of the initial orientation and deformation modes on the rolling texture of *(110)[hkl]* single crystals with a deflection of 5÷10° from the plane towards the direction of rolling was analyzed on the example of Fe–3%Si alloy.

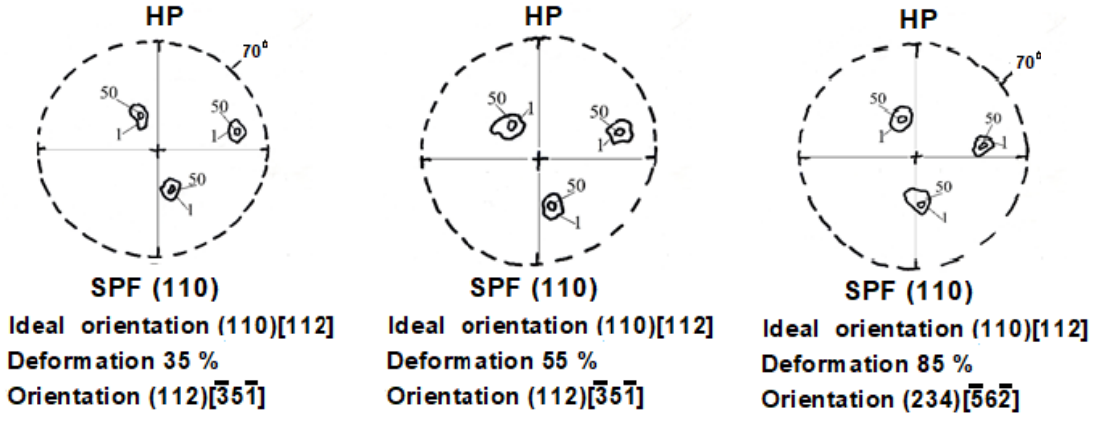
Three types of samples were rolled under laboratory conditions. The first group had $(110)[\bar{1}12]$ and $(110)[\bar{1}11]$ initial ideal orientation, with a deflection of 8 degrees from the plane towards the rolling direction. The second group had $(110)[\bar{3}31]$ and $(110)[\bar{5}51]$ initial ideal orientation, with a deflection of 7 degrees. The third group had $(110)[\bar{5}51]$ initial ideal orientation with a deflection of 5 degrees.

Samples were rolled on the laboratory rolling mill DUO-90 with the rolls diameter of 90 mm, at room temperature. The rolling was carried out without grease lubricant. The guides were used to prevent the rotation of samples. The cross-section of the original samples was 0,48×15,0 mm.

The formation of the rolling texture of the central layers of the first group had a similar character with the one described in the earlier papers [1÷7, 11÷13]. The main difference of the obtained results from the previous studies is that the orientation of the "group 1" deformed single crystals is single-component. Figures 1, 2 show {110} pole figures taken from the central layers of the Fe – 3%Si alloy of the specified group, rolled with reduction rate of 35%, 55% and 85%.

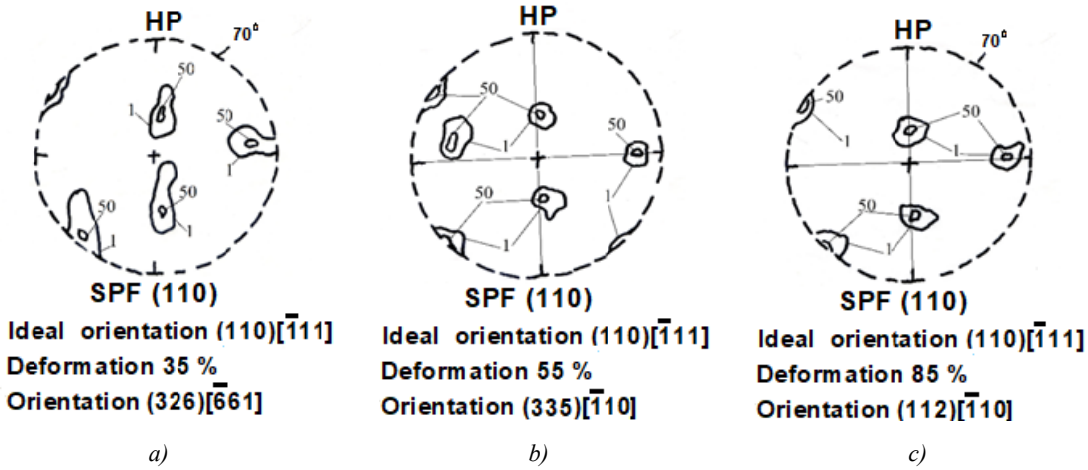
The analysis shows that *(110)[hkl]* orientation of Fe-3%Si alloy is one-component. The samples with $(\mathbf{110})[\bar{\mathbf{1}}\mathbf{12}]$ ideal orientation, at a reduction rate of 35% have orientation close to $(\mathbf{112})[\bar{\mathbf{3}}\mathbf{5}\bar{\mathbf{1}}]$ (Figure 1,a); the samples with $(\mathbf{110})[\bar{\mathbf{1}}\mathbf{11}]$ ideal orientation have the orientation close to $(\mathbf{326})[\bar{\mathbf{6}}\mathbf{61}]$ (figure 2,a). The latter sample also has dispersion around transverse rolling direction. The further increase of deformation rate reduces dispersion and almost does not change the orientation (figure 1b, figure 2b).

The sample with $(\mathbf{110})[\bar{\mathbf{1}}\mathbf{12}]$ ideal orientation, at a reduction rate of 85%, has orientation of the plane between (112) and (111); at the same time it is slightly shifted counterclockwise from the $[\bar{\mathbf{1}}\mathbf{10}]$ axis and can be recorded as $(\mathbf{234})[\bar{\mathbf{5}}\bar{\mathbf{6}}\bar{\mathbf{2}}]$ (figure 1, c). When the sample with $(\mathbf{110})[\bar{\mathbf{1}}\mathbf{11}]$ ideal orientation is deformed at a reduction rate of 85%, $(\mathbf{112})[\bar{\mathbf{1}}\mathbf{10}]$ orientation is one-component (figure 2, c).



a) *b)* *c)*

Figure 1 – Straight pole figures (110) of the central layers of the samples (*a*, *b*, *c*) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial $(\mathbf{110})[\bar{\mathbf{1}}\mathbf{12}]$ ideal orientation,; the reduction rate of a) – 35%; b) – 55%; c) – 85%



a) *b)* *c)*

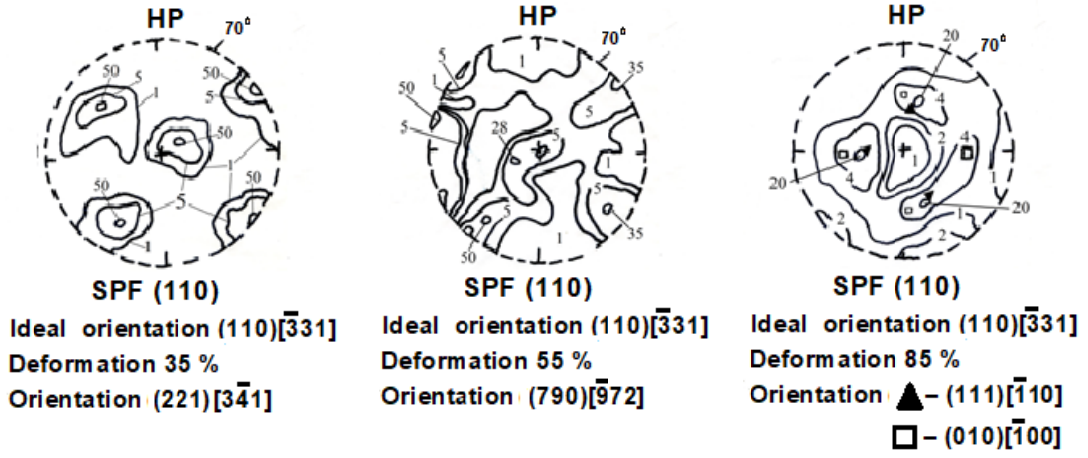
Figure 2 – Straight pole figures($\mathbf{110}$) of the central layers of the samples (a, b, c) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial ($\mathbf{110}$)[$\bar{\mathbf{1}}\mathbf{11}$] ideal orientation,; the reduction rate of a) – 35%; b) – 55%; c) – 85%

The formation of $(110)[hkl]$ rolling texture of central layers of $Fe-3\%\,Si$ alloy (groups 2 and 3), deflected along (110) plane towards the rolling direction of 7 and 5 degrees respectively, in general has a similar character with the one described in the earlier papers. Depending on the rolling conditions and initial orientation, it differs by the dispersion of orientations and the presence of the other weak components [8÷10, 14÷21].

The results of the radiographic analysis of the rolling groups 2 and 3 are presented in figures 3–5. The analysis of pole figures was carried out similarly to the first group. The data is presented in the table below.

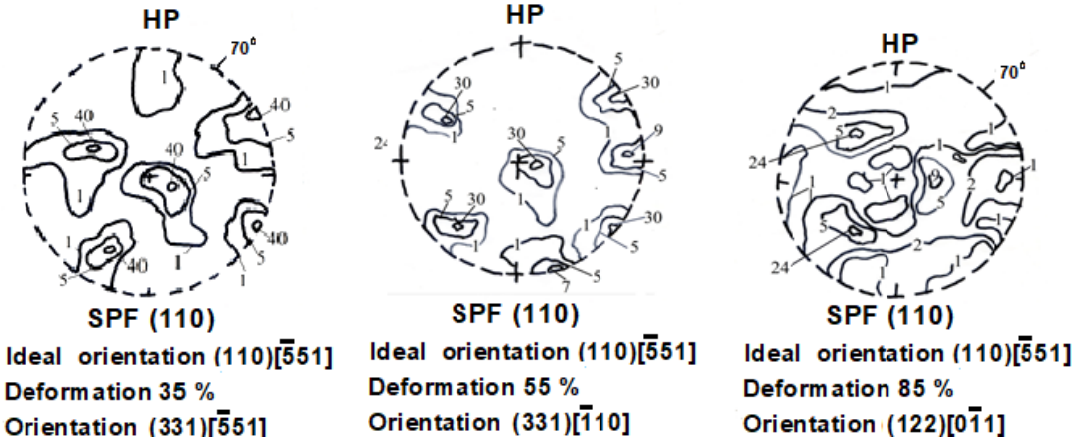
Thus, in the process of formation of $(110)[hkl]$ rolling texture of the central layers of Fe – 3%Si alloy with the deflection of 8 degrees from (110) plane towards the rolling direction, the following results were obtained. In all cases, the orientation appeared to be one-component, close to (112); in the case of [$\bar{\mathbf{1}}\mathbf{12}$] reference direction, it is close to $[\bar{5}6\bar{2}]$ direction; in the case of [$\bar{\mathbf{1}}\mathbf{11}$] reference direction, it is close to $[\bar{1}10]$ direction.

The analysis of texturing during the rolling process of single crystals of groups 2 and 3 showed that there is a similarity in texture formation. The main orientation in all the cases is $(111)[\bar{1}10]$, i.e. the single crystal rotates around $[\bar{1}10]$ crystallographic direction, close to the direction of rolling.



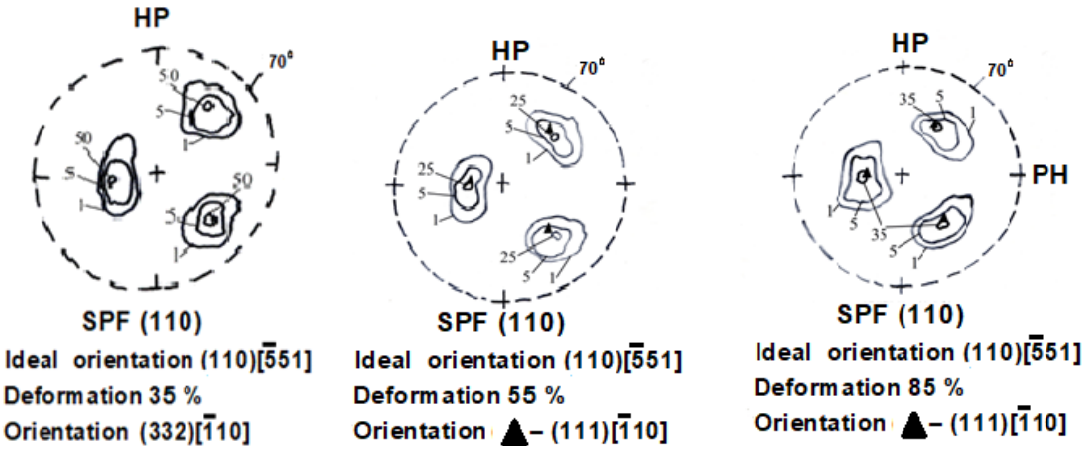
a) *b)* *c)*

Figure 3 – Straight pole figures($\mathbf{110}$) of the central layers of the samples (a, b, c) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial ($\mathbf{110}$)[$\bar{\mathbf{3}}\mathbf{31}$] ideal orientation; the reduction rate of a) – 35%; b) – 55%; c) – 85%



a) *b)* *c)*

Figure 4 – Straight pole figures(**110**) of the central layers of the samples (*a*, *b*, *c*) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial (**110**)[$\bar{5}$51] ideal orientation; the reduction rate of a) – 35%; b) – 55%; c) – 85%



a) *b)* *c)*

Figure 5 – Straight pole figures(**110**) of the central layers of the samples (*a*, *b*, *c*) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial (**110**)[$\bar{5}$51] ideal orientation; the reduction rate of a) – 35%; b) – 55%; c) – 85%

Radiographic analysis of the rolling groups 1-3 of Fe – 3%Si alloy

Group	Figure	Ideal orientation	Deflection from (110) plane [degrees]	Orientation after deformation:		
				35%	55%	85%
				Preliminary	Intermediate	Final orientation
1	1	(**110**)[$\bar{1}$**12**]	8	(**112**)[$\bar{3}$**51**]	(**112**)[$\bar{3}$**51**]	(**234**)[$\bar{5}$**62**]
	2	(**110**)[$\bar{1}$**11**]	8	(**326**)[$\bar{6}$**61**]	(**335**)[$\bar{1}$**10**]	(**112**)[$\bar{1}$**10**]
2	3	(**110**)[$\bar{3}$**31**]	7	(**221**)[$\bar{3}$**41**]	(**790**)[$\bar{9}$**72**]	(**111**)[$\bar{1}$**10**] (**0**濱**0**)[$\bar{1}$**00**]
	4	(**110**)[$\bar{5}$**51**]	7	(**331**)[$\bar{5}$**51**]	(**331**)[$\bar{1}$**10**]	(**122**)[0$\bar{1}$**1**]
3	5	(**110**)[$\bar{5}$**51**]	5	(332)[$\bar{1}$10]	(111)[$\bar{1}$10]	(111)[$\bar{1}$10]

The difference between the results concerning the analysis of alloys of groups 3 and 2 is the following: in the first case, a one-component (111)[$\bar{1}$10] orientation is formed, while in the second case almost always there is another weak orientation. It must be noted, that a one-component (111)[$\bar{1}$10] orientation is formed in the case of a small reduction rate during one rolling, whereas an increase in reduction leads to a two-component orientation.

Conclusions. In the process of studies of *rolling texture in the central layer of* Fe – 3%Si(110)[hkl] alloy, there were discovered some differences in the formation of the texture from those described earlier in the scientific and technical literature. It was established that during the rolling of Fe – 3%Si alloy along (110) plane deflected from the rolling plane around the transverse rolling direction, a single-component deformation texture is formed in the central layers, due to the action of symmetric slip systems.

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ДИАМЕТРІ 90 ММ БІЛІКТЕРМЕН ПРОКАТТАУ КЕЗІНДЕ Fe – 3%Si(110)[hkl] ҚОРЫТПАСЫНЫҢ ОРТАША ҚАБАТТАРЫНЫҢ ДЕФОРМАЦИЯЛАНУ ӨЗГЕШЕЛІКТЕРІ

Аннотация. Мақалада бастапқы кристаллографиялық бағдарлау мен деформациялау тәртіптерінің Fe – 3%Si(110)[hkl] қорытпасы монокристалдарының орташа қабатындағы илемдеу текстурасына әсерін зерттеу нәтижелері ұсынылады. Монокристалдар сынамаларының топтары зертханада илемденді. Сынамалар топтары деформациясының сонғы мөлшері бойынша, илемдеу жазықтығында жататын идеал кристаллографиялық бағдарлау бойынша және идеал бағдарлаудың жазықтығы бағытының илемдеу бағытынан ауытқуы бойынша жіктелді. Және де эксперимент жүргізу әдістемесімен бір өңдеу кезіндегі қысылу шамасы ескерілді. Илемдеу нәтижелерін зерттеу үшін рентгенографиялық әдіс пайдаланды. Рентгенографиялық зерттеудің нәтижелерін стереографиялық проекцияға салып тіке полюстәк фигуралар құралды. Тіке полюстік фигуралар талдау арқасында текстура қалыптасуының бұрын алынған нәтижелерден ауытқулары айқындалды. Сол ауытқулар мәні болып орташа қабатта деформацияның бір компонентті текстурасының пайда болуы табылады.

Түйін сөздер: монокристалдар деформациясы, кристаллографиялық текстура, стандарттық кристаллографиялық проекциялары, полюстік фигуралар, деформацияның текстуралары.

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ОСОБЕННОСТИ ДЕФОРМАЦИИ СРЕДНИХ СЛОЕВ СПЛАВА Fe – 3%Si(110)[hkl] ПРОКАТКОЙ С ДИАМЕТРОМ ВАЛКОВ 90 ММ

Аннотация. В статье предложены результаты исследования влияния исходной кристаллографической ориентировки и режимов деформации на текстуру прокатки в центральном слое монокристаллов сплава Fe – 3%Si(110)[hkl]. В лабораторных условиях были прокатаны группы образцов монокристаллов. Группы образцов были классифицированы по конечной величине деформации, по идеальной кристаллографической ориентировке, лежащей в плоскости прокатки, и по отклонениям направления плоскости идеальной ориентировки от направления прокатки. Методикой проведения эксперимента учитывалось также и величина обжатия за один подкат. Для исследования результатов прокатки был применен рентгенографический метод. Данные рентгенографического исследования накладывали на стереографическую проекцию и строили прямые полюсные фигуры. Результаты расшифровки прямых полюсных фигур выявили отличия в формировании текстуры от ранее полученных результатов. Эти отличия заключаются в проявлении в центральном слое однокомпонентной текстуры деформации.

Ключевые слова: деформация монокристаллов, кристаллографическая текстура, стандартные кристаллографические проекции, полюсные фигуры, текстуры деформации.

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REFERENCES

[1] Hu Hgun, Cline R.S. Rolling Texture in Aluminium-Iron Single Crystals // Trans of The Metallurgical society of AIME. 224. 784 p. (in Eng.).

[2] Avramov Y.S., Naumann G. Formation of recrystallization texture during rolling of Fe-Si single crystals (3%) of single crystal (110) in different crystallographic directions // Inorganic materials. 1967. Vol. 3, N 7. P. 1170-1173 (i.n Rus.).

[3] Avramov Y.S., Molotilov B.V., Naumann G., Samarina N. Mmm. The ratio between the deformation and recrystallization textures when rolling single crystals (110) of transformer steel in different directions // FMM. 1966. Vol. 21, N 5. P. 740-744 (in Rus.).

[4] Oplnsky A.J., Smoluchowski R. The Crystallographic Aspect on Slip Body-Centered Cubic Single Crystals. 2. Interpretation on Experiments // Journal of Applied Physics. 1951. Vol. 22, N 12. P. 1488-1492 (in Eng.).

[5] Hu K. Annealing of silicon-iron. Sat: Return and recrystallization of metals. M.: Metallurgy, 1966. P. 273-326 (in Rus.).

[6] Savinsky A.A., Goldstein V.Ya. Study of heterogeneity of texturearray during rolling of single crystals of silicon iron // Proceedings of the 3rd all-Union conference on textures and recrystallization in metals and alloys. Krasnoyarsk: KPI, 1982. P. 92-99 (in Rus.).

[7] Canadian L.B., Salnikova E.F. Dergach V. the asymmetry of the texture deformation of single crystals of silicon-iron // Proceedings of the AS of the USSR. Ser. Physical. 1979. Vol. 43, 7. P. 1385-1387 (in Rus.).

[8] Malashkevich P.I., Mishnev S.V. Texturepattern in the differential rolling of iron // Tesas. Doc. Proceedings of all-Union. conf. "Improving the durability and reliability of machines and drives", 22-24 September 1981, Kuibyshev. Kuibyshev: KPI, 1981. 354 p. (in Rus.).

[9] Mishnev S.V., Malashkevich P.I., Durnev V.D. Technology of production of textured sheet metal differential rolling // Bulletin of Kazan state technological university, mechanical engineering. Krasnoyarsk, 1999. P. 66-73 (in Rus.).

[10] Kurmangaliyev T.B., Sherov K.T., Sikhimbayev M.R., Absadykov B.N. et al. Experimental study of optimal parameters of pneumatic motor of vibration table for inertial vibroabrasive machining the parts on the basis of beryllium oxide // News of the Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. N 5. P. 184-191. https://doi.org/10.32014/2018.2518-170X.24 ISSN 2518-170X (Online), ISSN 2224-5278 (Print) (in Eng.).

[11] Sherov K.T., Sikhimbayev M.R., Absadykov B.N. et al. Control's accuracy improvement and reduction of labor content in adapting of ways of metalcutting tools // News of the Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. N 6. P. 170-179. doi: 10.32014/2018.2518-170X.47 (in Eng.).

[12] Sikhimbayev M.R., Sherov K.T., Zharkevich O.M. et al. Experimental studies of stabilization of boring cutter form-building top oscillation // Journal of Vibroengineering. Kaunas, June 2012. Vol. 14, Issue 2 (792). P. 661-670 (in Eng.).

[13] Berezyuk V., Kuzembayev S., Sherov K., Sikhimbayev M., Mishnev S. et al. Increase of precision of casting blocks by applying acoustical oscillations in gas-impulsive moulding // Journal of Vibroengineering. The Lithuanian Academy of Sciences. Kaunas, August 2015. Vol. 17, Issue 5(1667). P. 2178-2185 (in Eng.).

[14] Babareka A.A. The texture of metals and alloys. Results of science and technology. M.: VINITI an SSSR, 1980. P. 79-148 (in Rus.).

[15] Wasserman Greven I. Textures of metallic materials. M.: Metallurgy, 1969. 654 p. (in Rus.).

[16] Smirnov V.S., Durnev V.D. Texture formation of metals during rolling. M.: Metallurgy, 1971. 254 p. (in Rus.).

[17] Vishnyakov Ya.D., Babareka A.A. and others. The theory of formation of textures in metals and alloys. M.: Science, 1979. 343 p. (in Rus.).

[18] Durnev V.D., Talashkevich I.P. Symmetry in technology. SPb.: Polytechnic, 1993. 256 p. (in Rus.).

[19] Talashkevich P.I., Mishnev S.V. Symmetry textures of metals at a consistent rolling // Tesas. Doc. III all-Union conference on textures and recrystallization in metals and alloys. Krasnoyarsk: KPI, 1980. P. 10-12 (in Rus.).

[20] Talashkevich P.I., Mishnev S.V., Slavov V.I. Symmetry of textures in parallel rolling // Tesas. Doc. III all-Union conference on textures and recrystallization in metals and alloys. Krasnoyarsk: KPI, 1980. 12 p. (in Rus.).

[21] Talashkevich I.P., Slavov V.I. On the symmetry of textures and their orientation in cubic metals // WPI. AS USSR, ser. Physical. 1979. Vol. 43, N 7. P. 1380-1384 (in Rus.).

[22] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

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ON THE CHOICE OF OPTIMAL PARAMETERS FOR THE INTEGRATED ASSESSMENT OF SURFACE WATER QUALITY

Abstract. A review of the literature on the selection of optimal indicators for the integrated assessment of surface water quality is given. The restriction of the amount of polluting ingredients analyzed in the water is indicated in the Kazhydromet system, which to a certain extent results in a water quality assessment of the results that do not correspond to the actual ecological and toxicological state of the reservoir.

The need for state monitoring of the level of accumulation and spread of persistent organic pollutants (POPs): organochlorine pesticides (CVD) and polychlorinated biphenyls (PCBs) in the water bodies of the Republic of Kazakhstan is reasonably justified on the basis of: high toxicity for living organisms and the environment, extreme stability in natural environments , active migration capacity in nature and trofical chains, existing in the RK, powerful sources of pollution of natural and water bodies, pollution the strict adherence to the Stockholm Convention on POPs, ratified by it in 2007. Contamination with these dangerous xenobiotics of some reservoirs of the Russian Federation and a number of large water objects of the Republic of Kazakhstan is shown on the basis of a generalization of the literary data, as well as the results of the author's own research into various periods. The level of contamination of water, biological resources and atmospheric precipitation of the Ile-Balkhash basin with highly toxic PCBs is graphically illustrated on the basis of the monograph on POPs published in Kazakhstan for the first time.

On the basis of irrefutable scientific data, the need to monitor the dynamics of POPs for objective assessment of water quality in the water bodies of the Republic of Kazakhstan, especially large transboundary water basins, is proved.

Key words: integrated assessment of water quality, persistent organic pollutants, sources of pollution.

Introduction. In contemporary conditions, hundreds and thousands of new chemicals created by humans enter the biosphere. They are different in composition and different in the degree of toxicity for the natural environment and living organisms. As a result of anthropogenic impact, the natural environment is transformed into a qualitatively different state [1, 2]. According to the data of L.A. Kulsky and V.V. Dal [3], up to 20000 chemical substances are present in the aquatic environment as part of the noosphere. Many of these compounds did not previously exist in nature, including in the aquatic environment and their transformation when interacting with water creates a number of negative consequences for the water body and for certain elements in the tropical chain.

Anthropogenic pollution and water bodies are exposed to Kazakhstan. An example is Lake Balkhash, the ecological state of which is significantly deteriorated under the influence of sewage and aerial emissions from industrial enterprises [4-6]. Under the influence of anthropogenic factors, the aquatic ecosystem of Lake Kopa is degraded [7], the transboundary river Zhayik (Ural) [8, 9] is subject to high man-made pollution.

The multi-component nature of the composition of surface waters and its high dynamism in time and space naturally require the use of sophisticated methods for a reliable assessment of their quality. The

urgency of these problems is well known. Optimization of water quality assessment methods is an important factor not only in solving practical problems of a local nature, but also in developing the scientific basis for forecasting the state of ecosystems of water bodies in general.

Currently, the solution of these problems is paid a lot of attention from scientists in many countries. Methods for the integrated assessment of the quality of surface waters are constantly being improved; various options have been proposed that clarify and supplement to some extent existing methods [10-12].

One of the important issues in the calculation of integral indices is the justification of the choice of the optimal parameters of water quality, on which integrated assessments should be based. On this issue in the review article V.A. Zubarev [13] presents different approaches of researchers. According to Yu.V. Novikov [14, 15], to assess the quality of water, it is necessary to use indicators with established MPCs, which can be formed as a result of chemical and biological transformations and integral indicators that have standards. Different experts recommend the most diverse number of indicators for constructing formalized assessments of water quality. C.M. Margolina et al. [16] recommended taking into account 30-40 characteristics, D. Dunnete [17] – 14, E.A. Lebedeva [18] – 6, I.V. Grib [19] – 15 indicators, etc. According to [13], most researchers base their comprehensive assessments on 9-15 water quality ingredients.

Quite essential recommendations for choosing the optimal water quality parameters for the calculation of the Integrated water pollution indices (IWPI) are given in the work of M.Zh. Burlibaev [11]. It deals with the need to take into account, when calculating the IWPI, analytical data on the concentration of organochlorine pesticides (OCPs) in the waters of water bodies and streams.

This issue is very important for Kazakhstan due to the fact that there are powerful sources of pollution of water bodies on its territory with persistent organic pollutants (POPs), which include OCPs, which will be discussed in more detail below.

This issue is very important for Kazakhstan due to the fact that there are powerful sources of pollution of water bodies on its territory with persistent organic pollutants (POPs), which include OCPs, which will be discussed in more detail below.

The basis for this author's statement is that for carrying out a comprehensive assessment of surface water pollution in Kazakhstan, recommended for implementation in the network of RSE «Kazgidromet» «Guidelines for formalized comprehensive assessment of the quality of surface and sea water by hydrochemical indicators», published in 1988 [20]. And in the official publications in Kazakhstan (Yearbooks, Information Bulletins, etc.), compiled according to the specified «Methodological recommendations», the amount of analyzed pollutants is strictly limited, for surface waters 6 and for sea waters 4 indicators. However, data on highly toxic compounds, such as pesticides, are not taken into account. Even for such rivers as the Syrdarya and Zhaiyk (Ural) data on pesticides are not given, although pesticides for these rivers still remain priority polluters [21, 22].

Persistent organic pollutants. The validity of the recommendations for inclusion in the calculation lies primarily in the fact that OCPs (DDT, aldrin, hexachlorobenzene, HCH, etc.), as well as polychlorinated biphenyls (PCBs), which are also highly toxic for living organisms extremely low levels of concentration in natural objects. Xenobiotics are characterized by high resistance to physical, chemical and biological factors, global prevalence by air, water and migratory species, high cumulative ability in living organisms, and active migration through trophic networks. Unlike poisons that affect certain organs, these toxicants destroy the system of internal regulation, violate the human reproductive system, endocrine and immune status of a person and therefore are called endocrine disruptors. They have chronic toxicity, which is manifested in various pathological changes at the molecular-genetic, cellular-tissue and behavioral levels [23-26].

POPs are recognized by the international community as substances that pose a great danger to human health and the environment. To take measures to protect humans and the environment in 2001, a global international agreement was adopted – the Stockholm Convention on POPs [27]. It entered into force in 2004, Kazakhstan ratified it in 2007. The convention sets goals: immediate cessation of production of POPs, cessation by 2025 of their use and destruction of all wastes no later than 2028 using environmentally friendly methods.

Global and regional distribution of POPs, includes OCPs and PCBs have led to their being recorded everywhere in the most remote areas of the world, including the Arctic and Antarctica [28-30]. As we

know, by the end of the 80s there was a tendency to reduce the level of pollution of the natural environment of OCPs due to the reduction of their mass use in agriculture. However, according to the available literature data and data of official state bodies, there are quite powerful anthropogenic sources of toxic POPs into the environment in different countries at present.

Extremely high resistance of DDT and other OCPs in the soil, according to [31, 32], is determined by the exoticness of their molecules for microorganisms and as a result in the soil they undergo only partial transformation, remaining in the environment as potential sources of its pollution. According to the authors, the duration and length of the process of the release of residues of DDT and HCH into surface waters for many years is related to the fact that they are very short in leaching and leaching from the soil and are tenths of a percent per year. OCPs that have fallen into surface runoff and collector-drainage systems, make further migration in water bodies, undergoing sedimentation to bottom sediments with sediments, cumulation with aquatic flora and fauna. All this causes a long period of finding OCPs in the natural environment, includes in surface waters.

Exponential calculations showed [31,33,34] that at the junction of the forest, steppe and steppe zones, the period of almost complete disappearance of residues of DDT and HCH from soils was within 22-152 years, in the zone of dry steppes and semi-deserts – 14-142 years.

According to data [35, 36], high persistence of POPs in the environment caused the formation of their impact zones on land and in the coastal part of the seas, characterized by an abnormally high content compared to background amounts of substances in soil, water and bottom sediments. As an example, the authors cite the south-eastern region of the Azov Sea and the delta river Kuban, where according to the results of their research, high soil contamination from rice, wheat, cabbage, bottom sediments of water bodies, and a number of food products – milk, meat, potatoes, etc. – was found. Coastal parts of Yellow, Black and the Caspian Sea [37-39].

The scientific literature often contains information about the discovery in the last decade of a fairly high pollution of the ecosystems of the Caspian Sea and some large water bodies of the Russian Federation and Kazakhstan. According to [40], in the bottom sediments of the northwestern part of the Caspian Sea in 2012 and 2013 the total concentration of OCPs reached 4,87 μg/kg, and the metabolites of DDT – 4,72 μg/kg, the contents of PCB and hexachlorobenzene were 10,8 and 0,30 μg/kg respectively. The highest concentrations of PCBs are recorded in the sediments of the Middle Caspian, and the OCP compounds in the sediments of the coastal waters, where they come from surface runoff. It was also noted that the POP content in marine sediments remained at about the same level as recorded in 2002, which is explained by the authors for their high environmental sustainability and the presence of local sources of pollution in the sea.

Results and discussion on organochlorine pesticides. The results of ecological and toxicological studies conducted by us also indicate pesticidal pollution of the Kazakh waters of the Caspian Sea and the mouth areas of the Zhaiyk (Ural) and Kigash rivers (eastern branches of the Volga river delta). The highest level of pesticide contamination was recorded in the water of the north-western water area of the Kazakhstan sector, which is under the influence of the Volga runoff. The total concentration of DDT and HCH in the waters of this zone varied in 2003-2005 from 6,01 to 20,02 μg/dm^3, and in 2008 and 2009 from 8,88 to 51,80 μg/dm^3. The values of this indicator were in the water river Zhaiyk within 0,21-3,02 μg/dm^3, in water river Kigash – 0,81-9,04 μg/dm^3 [22, 41]. The accumulation of pesticides in the muscles of various fish species was: DDT in sturgeon up to 40 μg/kg, in part fish species up to 20 μg/kg in carp and up to 140 μg/kg in bream muscles, and the HCH content was on average about 2,0 μg/kg.

In recent years, a number of publications have appeared in the scientific literature devoted to the study of persistent organochlorine pesticides in the ecosystem of other large water bodies of the Russian Federation [23, 42-46] and Kazakhstan [47-50]. One of the main reservoirs of the republic lake Balkash is subject to pesticide pollution. According to our unpublished data for 2012, the amount of OCPs in the water of certain parts of the lake was on average from 0,075 to 0,376 μg/dm^3. The values of this indicator in the waters of the rivers flowing into the lake reached 0,512 and 0,622 μg/dm^3. The isomers of HCCH, heptachlor, aldrin and DDT metabolites are registered in the fish of the fish inhabiting the lake; their total accumulation in the muscle tissues of fish reached 4,91 and 5,58 μg/kg by average values. All this clearly demonstrates the continuing negative impact of pesticides on water bodies. Consequently, the problem of protecting the environment from their influence still exists.

It should be noted that such a problem is quite acute for Kazakhstan. It is related to the fact that according to the latest data from the Ministry of Energy of the Republic of Kazakhstan [51], for the month of April 2014, the total number of obsolete, prohibited and unsuitable to use pesticides stored at various facilities in Kazakhstan is 1 617 638 kg (l), containers of – under them more than 169660 pieces. They are not disposed of due to insufficient capacity of processing enterprises. Large amounts of obsolete pesticides were buried at the landfill sites in the 1960s – 1980s, but there is no information about the location and the number of buried pesticides in the archives.

According to the available information [52], only within the Pavlodar region, unutilized pesticides are stored in the territories of pesticide warehouses located near settlements: Zhetekshi, 7-Aul, Kalkaman and in the Derzhavinsky agricultural complex. In this source, based on a study of the Regional Center for POPs in Brno (led by Ivan Cholubek), data are also being provided on air pollution of the vast territory of Kazakhstan by such pesticides as DDT, hexachlorobenzene and lindane.

The above materials about the continuing pesticide pollution of the republic's water bodies and non-reclaimed pesticides stored on its territory suggest that the termination of RSE «Kazhydromet» in the last decade of state monitoring of OCP compounds in Kazakhstan's water bodies is unreasonable and premature. The neglect of the concentration of these xenobiotics in assessing the quality of water resources to a certain extent leads to incorrect results, a distortion of the existing state of the quality of the aquatic environment in water bodies.

The need to monitor for OCPs in the water bodies of Kazakhstan and to take into account data on their concentration in assessing the quality of water resources can be quite clearly shown by the example of one of our work [53]. In it the assessment of the water quality of the lakes Alakol group was given on the basis of the results of its own research for 2004-2010, and materials on the content of OCPs (HCH and DDT) in lake waters were available for 2004-2006. In the water of the lake Alakol concentration of DDT metabolites was 0,2 μg/dm^3, isomers of HCH from 0,005 to 0,04 μg/dm^3, and in the water lake Sasykkol was present only isomers of HCH in the range of 0,01-0,03 μg/dm^3.

As we known, pesticides should not be present in the water of fishery bodies of water, i.e. Their maximum permissible concentrations are equal to 0. In our calculations for the maximum permissible concentrations of these xenobiotics, the resolution of an atomic spectrophotometer of 0,001 μg/dm^3 is conventionally taken according to recommendations [11, 12].

For clarity, the table selectively shows the calculation results for 2004-2006 only. From which it follows that the main increase in pollution of lake waters in these years was due to DDD and HCH. The range of fluctuations of the WPI values according to these toxicants (taking into account the hazard class (h.c.)) in the water of lake Alakol was in the range of 40 and 5, and for the lake Sasykkol from 10 to 30.

As can be seen from the table, the weighted average IWPI in the water of lake Alakol varied in 2004-2006 from 2,3 to 20, in the water of the lake Sasykkol – from 4,3 to 11. The maximum for both reservoirs was registered in 2005 due to elevated concentrations of pesticides and heavy metals.

In the classification of water bodies according to the results of the IWPI, taking into account the hazard class of ingredients, the following results were obtained: water lake Alakol with the joint presence of pesticides and metals in 2004 and 2005 was characterized by «extremely high levels of pollution» (IWPIa.w. – 15 and 20, respectively), and in 2006 – classified as «moderately polluted». Water lake Sasykkol in 2004 and 2006 classified as «high level of pollution», and in 2005 – «extremely high level of pollution» (IWPI – 11). In 2007-2010 the water resources of the lakes under consideration belonged to the classes of «moderate» and «high» pollution, mainly due to elevated concentrations of certain metals and nitrogen compounds.

Polychlorinated biphenyls. Above mentioned problems associated with continuing pollution of the environment, including water resources, organochlorine pesticides, used mainly in the agricultural sector. At present, environmental pollution with polychlorinated biphenyls (PCBs), which are also on the POPs list, is an even more acute environmental problem. These so-called technical POPs, have a higher level of toxicity for the natural environment and living organisms. Sources of entry of PCBs into the natural environment are leaks from transformers, condensers, heat exchangers, evaporation from various technical installations, where they are used as dielectrics, liquid industrial waste. An important role in the distribution in nature of PCBs is played by their emissions into the atmosphere from the incineration of urban garbage and various solid wastes.

Integrated water pollution indices (IWPI) lakes Alakol and Sasykkol taking into account the hazard class

Year	Indicators	Lake Alakol		Lake Sasykkol	
		with h.c.	IWPI a.w.	with h.c.	IWPI a.w.
2004	IWPI K1=∑WPI (HCH)/n	10,0	15	10	4,9
	IWPI K2=∑WPI (DDT+Pb+Cd)/n	34,5		3,8	
	IWPI K3=∑WPI (NH_4+Cu+Zn+Ni)/n	1,8		1,0	
2005	IWPI K1=∑WPI (HCH)/n	40	20	30	11
	IWPI K2=∑WPI (DDT+Pb+Cd)/n	–		0,6	
	IWPI K3=∑WPI (NH_4+Cu+Zn+Ni)/n	1,2		2,9	
2006	IWPI K1=∑WPI (HCH)/n	5,0	2,3	10	4,3
	IWPI K2=∑WPI (DDT+Pb+Cd)/n	0,6		0,9	
	IWPI K3=∑WPI (NH_4+Cu+Zn+Ni)/n	1,3		2,1	

If the problems with respect to OCPs, as briefly outlined above, are in the continued impact on aquatic ecosystems of residual accumulated in natural objects and stored (in various states) unutilized pesticide stocks, then for PCBs we are talking about the increasing rate of environmental pollution by these xenobiotics places to a critical level.

Environmental problems associated with the widespread occurrence of PCBs on the planet, the increase in their negative effects on the environment, along with the insufficiency of measures taken to prevent their dangerous consequences, according to scientists and specialists, are global in scope. At present, many scientific publications, mainly foreign authors, are devoted to this problem.

Here without extending to the essence, urgency and diversity of this problem, it seems sufficient to refer to the work [54], which represents the first significant scientific generalization of literary and official information on POPs issues published in Kazakhstan, against the background of detailed studies of their contamination level aquatic ecosystem of one of the main basins of the republic. Below we only briefly note the following.

According to the results of the preliminary inventory, there are eight «hot spots» in the country contaminated with PCBs. The main polluted area is the territory of the city of Oskemen, where the waste of the Condenser Plant was buried in a storage pond. Other PCB-polluted areas are the Zhangiz-Tobinsky and Derzhavinsky polygons for the destruction of military equipment, the Saryshagan polygon, the areas of the northern and western shores of the Balkash lake, Ekibastuz and Kostanay substations, as well as substations at the Kostenko mine in Karaganda. The total area of pollution is 2500 hectares.

On the territory of the republic there are PCB-containing equipment in the amount of 116 transformers and about 50 thousand capacitors. The amount of PCB they contain is estimated at 800 tons. These equipments present a potential hazard if they are depressurized. In terms of POPs waste stocks, Kazakhstan ranks second among the countries of Central and Eastern Europe and CIS countries after Russia.

In the natural objects and the ecosystem of water bodies of Kazakhstan, targeted monitoring, in order to implement the national objectives of the Stockholm Convention on POPs, is practically not carried out. Observation of these xenobiotics is not conducted by the network of Kazhydromet and other nature protection bodies of the Republic of Kazakhstan. The «Convention on Environmental Safety of the Republic of Kazakhstan for 2004-2015» indicates the absence in Kazakhstan of an objective assessment of the environmental pollution of POPs. The need to develop a program for the control, monitoring and management of POPs was stressed during 2005-2006. However, there is no information in the scientific literature and periodicals of the Ministry of Energy about conducting any significant observations on the spread of POPs, including PCB, in the objects of the environment of the republic.

Currently some information about the levels of accumulation of PCBs are available from natural sites in the Oskemen region, which is one of 8-«hot spots » points – areas contaminated with PCBs, as well as more detailed materials obtained from the water bodies of the Ile-Balkhash basin [54]. These scientific data indicate that PCBs pollute aquatic and biological resources, snow cover and soil in some cases to a high level.

This information characterizes the toxicological state of one of eight «hot spots» – territories contaminated with PCBs. And what is the toxic atmosphere on the other «points»? Unfortunately, it is not known, there is no information on the pages of accessible scientific and operational publications due to the lack of monitoring by state environmental agencies, although there are many localities in the region of these very dangerous for human health and food resources are produced.

Some data on the level of PCB concentration in water and fish of the Shardara, Bukhtarma, Kapshagai reservoirs, the Small Aral sea and the Zhayik river were obtained by us in the last decades of the last century [21, 22, 41, 47-50].

The above information is evidence that highly toxic PCBs are widespread in ecosystem facilities of Kazakhstan's water bodies. However the State monitoring of the level of pollution and their impact on natural objects, water resources is not conducted even in the existing highly polluted areas, where there are powerful sources affecting the environment. Continuous monitoring and monitoring of the distribution of PCBs in the natural environment, as well as the establishment of systems of general public information on their results, comply with the requirements of the Stockholm Convention on POPs.

In the Russian Federation, for instance, Roshydromet conducts monitoring of environmental pollution by chemical POPs compounds. The monitoring results are published in the «Reviews» and «Yearbooks». Permanent monitoring of these substances is conducted by five specialized regional research centers. Large-scale research conducted by many scientific institutions.

Conclusion. The official data set out in the article about the huge amount of stored unutilized OCP reserves and numerous contaminated PCBs in the territory of Kazakhstan, including many in the form of used transformers and capacitors, indicate the existence of powerful sources of environmental pollution by POPs compounds. And the results of generally limited research in recent years convincingly show a fairly high level of pollution of the natural environment, including aquatic and biological resources. The lack of State monitoring and analytical data on the levels of POPs accumulation in the country's surface waters, naturally, does not allow an objective assessment of the existing state of the quality of water resources, especially in large transboundary basins.

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ЖЕР БЕТІ СУЛАРЫНЫҢ САПАСЫН КЕШЕНДІ БАҒАЛАУДА ОҢТАЙЛЫ КӨРСЕТКІШТЕРДІ ТАҢДАУ ТУРАЛЫ МӘСЕЛЕГЕ

Аннотация. Жер беті суларының сапасын кешенді бағалау үшін оңтайлы көрсеткіштерді таңдау бойынша әдеби мәліметтерге шолу келтірілген. Қазгидромет жүйесінде судағы талданатын ластаушы ингредиенттердің санының шектеулі болуынан, су сапасын бағалау кезіндегі нәтижелер су қойманың нақты экологиятоксикологиялық жағдайымен сәйкес келмейтіндігі көрсетілген.

ҚР су нысандарында тұрақты органикалық ластағыштар (ТОЛ): хлорорганикалық пестицидтер (ХОП) және полихлорлы бифенилдердің (ПХБ) таралуы мен жинақталу деңгейіне мемлекеттік мониторинг жүргізу қажеттілігі – олардың тірі организмдер мен қоршаған орта үшін жоғары улылығы мен табиғи ортадағы аса

тұрақтылығы, табиғаттағы және трофикалық тізбек бойынша белсенді миграциялық қабілеті, ҚР аумағындағы қуатты ластаушы көздерімен табиғи және су нысандарының ластануы, ластанған ошақтар және Қазақстан 2007 жылы ратификациялаған ТОЛ туралы Стокгольм конвенциясы бойынша қабылданған міндеттерді орындау үшін қажеттілігі негізді дәлелденген. ҚР ірі су нысандары мен РФ су қоймаларының осы қауіпті ксенобиотиктермен ластануы әдеби мәліметтермен, сонымен қатар авторлардың әртүрлі кезеңдерде жүргізген өз зерттеулері нәтижелері негізінде көрсетілген. Іле-Балқаш алабының су және биологиялық ресурстары мен атмосфералық жауын-шашындарының аса улы ПХБ ластану деңгейі, ТОЛ мәселесі бойынша Қазақстанда алғаш шығарылған монографияға енген мәліметтерде көрнекі суреттелген.

ҚР су қоймаларының әсіресе ірі трансшекаралық су алабтарының су сапасын шынайы бағалау үшін, ТОЛ деңгейіне мониторинг жүргізу қажеттілігі ғылыми мәліметтер негізінде дәлелденген.

Түйін сөздер: су сапасын кешенді бағалау, тұрақты органикалық ластағыштар, ластағыш көздер.

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К ВОПРОСУ ВЫБОРА ОПТИМАЛЬНЫХ ПАРАМЕТРОВ ПРИ КОМПЛЕКСНОЙ ОЦЕНКЕ КАЧЕСТВА ПОВЕРХНОСТНЫХ ВОД

Аннотация. Приводится обзор литературных сведений по вопросам выбора оптимальных показателей для комплексной оценки качества поверхностных вод. Указано на существующее в системе Казгидромет ограничение количества анализируемых в воде загрязняющих ингредиентов, что в известной мере приводит при оценке качества вод к результатам, несоответствующим действительно существующему эколого-токсикологическому состоянию водоема.

Необходимость государственного мониторинга за уровнем накопления и распространением стойких органических загрязнителей (СОЗ): хлорорганических пестицидов (ХОП) и полихлорированных бифенилов (ПХБ) в водных объектах РК аргументированно обоснована на основании: высокой их токсичности для живых организмов и окружающей среды, чрезвычайной устойчивости в природных средах, активной миграционной способности в природе и по трофическим цепям, существующих на территории РК мощных источников загрязнения ими природных и водных объектов, загрязненных очагов, строгой необходимости для Казахстана выполнение принятых обязательств по Стокгольмской конвенции о СОЗ, ратифицированной им в 2007 г. Загрязненность этими опасными ксенобиотиками некоторых водоемов РФ и ряда крупных водных объектов РК показана на основе обобщения литературных сведений, а также результатов собственных исследований авторов в разные периоды. Уровень загрязнения высокотоксичными ПХБ водных, биологических ресурсов и атмосферных осадков Иле-Балкашского бассейна наглядно иллюстрирован на материале, вошедшего в основу впервые изданной в Казахстане монографии по проблемам СОЗ.

На основе неопревержимых научных данных доказана необходимость мониторинга за динамикой СОЗ для объективной оценки качества вод водоемов РК особенно крупных трансграничных водных бассейнов.

Ключевые слова: комплексная оценка качества вод, стойкие органические загрязнители, источники загрязнения.

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REFERENCES

[1] Absametov M.K., Adenova D.K., Nusupova A.B. (2019) Assessment of the impact of anthropogenic factors water resources of Kazakhstan // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1, N 433 P. 248-254. https://doi.org/10.32014/2019.2518-170X.30 ISSN 2224-5278 (Print).

[2] Mukhamedzhanov M.A., Sagin Jai, Kazanbaeva L.M., Rakhmetov I.K. (2018) Influence of anthropogenic factors on hydrogeochemical conditions of underground drinking waters of Kazakhstan // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 5, N 431. P. 6-8. https://doi.org/10.32014/2018.2518-170X.1 ISSN 2224-5278 (Print).

[3] Kulsky L., Dal V. Problems of clean water. Kiev, 1974. 227 p.

[4] Amirgaliev N.A., Timirkhanov S.R., Isbekov K.B. Water resources of Kazakhstan: assessment, forecast, management. Vol. XIV. Kazakhstan's Fisheries: State and Prospects (DSP). Karaganda: «ARKO» Printing house, 2012. 667 p.

[5] Sala R., Deom J.M., Nigmatova S., Endo K., Kubota J. Soviet, Balkhash lake, recent and planned // News of the NAS RK. 2016. Vol. 2, N 416. P. 78-86.

[6] Madibekov A.S., Nysanbaeva, M.S., Kurmanova M. (2018) Role of the chemical composition of an atmospheric precipitation in pollution of a surface water // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 5, N 431. P. 120-127. https://doi.org/10.32014/2018.2518-170X.17 ISSN 2224-5278 (Print).

[7] Kazangapova N.B., Kunshygar D.Zh., Romanova S.M. The hydrochemical characteristic of lake Kopa // News of the NAS RK. 2016. Vol. 4, № 418. P. 79-84.

[8] Pavleichik V.M., Sivokhip Zh.T. Formation of the quality of surface waters in the basin of the upper reaches of the Ural River in the conditions of technogenic transformation of the natural environment // Water Resources. 2013. Vol. 40. P. 456-467.

[9] Medeu A.R., Amirgaliev N.A., Davtlegaliev S.K., Sergaliev N.Kh., Akhmedenov K.M. Assessment of the water resources of the transboundary rivers of the Ural-Caspian basin // Geoecological problems of the steppe regions: Materials International Scientific and Practical Conference. Orenburg, 2017. P. 32-46.

[10] Nikanorov A.M., Emelyanova V.P. Complex assessment of the quality of surface land water // Water Resources. 2001. Vol. 32, N 1. P. 61-69.

[11] Burlibaev M.Zh. Theoretical Foundations of Sustainability of the Ecosystem of the Transzonal Rivers of Kazakhstan. Almaty: Kaganat, 2007. 515 p.

[12] Burlibaev M.Zh., Baymanov Zh.N., Tazhmagambetov Ye.A. Comprehensive assessment of surface water quality by hydrochemical indicators. Almaty: Ylym, 2007. 95 p.

[13] Zubarev V.A. Hydrochemical indices of surface water quality assessment // Regional problems. 2014. Vol. 17, N 2. P. 71-77.

[14] Novikov Yu.V., Plitman S.I., Lastochkina K.O., Khvastunov R.M. Water Quality Assessment by Complex Indicators // Hygiene and Sanitation. 1984. N 11. P. 17-19.

[15] Novikov Yu.V., Plitman S.I., Lastochkina K.O., Khvastunov R.M. The use of complex indicators in the development of hygienic classification of water bodies according to the degree of their pollution // Hygiene and Sanitation. 1984. N 6. P. 11-13.

[16] Margolina S.M., Rokhlin G.M. On a comprehensive assessment of the degree of pollution of water bodies // Proceedings of the Institute of Applied Geophysics. 1977. Vol. 35. P. 99-100.

[17] Dunette D.A. A geographically variable water quality index used in Oregon // Water Pollution Cont. 1979. Vol. 51, N 1. P. 53-70.

[18] Lebedeva Ye.A. On surface water quality assessments // Questions of the organization of regional geographic information: mes. report 3 region. wk a seminar. Vladivostok, 1987. P. 76-77.

[19] Grib O.N. Clarification of the method of calculating the daily consumption of mineral substances on the small rivers of the Crimea // Meteorology, climatology and hydrology. 2005. N 49. P. 511-519.

[20] Guidelines for the formalized integrated assessment of the quality of surface and sea waters by hydrochemical indicators // USSR State Committee on Hydromet, Office of Observations and Control of Environmental Pollution. M., 1988. 12 p.

[21] Amirgaliev N.A. Aral-Syrdarya basin: hydrochemistry and problems of aquatic toxicology. Almaty: Bastau, 2007. 224 p.

[22] Amirgaliev N.A. Ecological and toxicological state of the Ural-Caspian basin and some priority directions of its research // Materials of intern. scientific and practical conference «The current state and ways to improve scientific research in the Caspian basin» (May 16-18, 2006; Astrakhan). Astrakhan, 2006. P. 21-24.

[23] Chuyko G.M., Yurchenko V.V., Brodsky E.S. Persistent Organic Pollutants in the Rybinsk Reservoir Ecosystem (Analytical Review) // Proc. «The current state of bioresources of inland waters». M.: Publishing house «AQUAROS», 2011. Vol. 2. P. 801-808.

[24] Borlakoglu J.T., Heagele K.D. Comparative aspects on the bioaccumulation, metabolism and toxicity with PCBs // Comp. Biochem. Physiol. 1991. Vol. 100, N 3. P. 327-338.

[25] Zhakovskaya Z.A., Petrova V.N., Khoroshko L.O. Polychlorinated biphenyls and hydrocarbons in the bottom sediments of the rivers in the basin of the r. Pechora // Water resources. Vol. 37, N 1. P. 75-83.

[26] German A.V., Lawn V.V. Accumulation of polychlorinated biphenyls in the Sheksninsky reach of the Rybinsk reservoir // Water Resources. 2003. Vol. 30, N 5. P. 571-575.

[27] Stockholm Convention on Persistent Organic Pollutants. Stockholm, 2001. 53 p.

[28] Afanasyev, M.I., Buivolov, Yu.A., Vulykh, N.K., Bozhina, A.N. Background organochlorine pesticides and polychlorinated biphenyls in natural media (according to world data) Message 6 // Monitoring of background environmental pollution. L.: Gidrometeoizdat, 1991. P. 57-80.

[29] Laletin N.A. Migration of persistent organic pollutants in freshwater objects about. West Spitsbergen (Lake Bienda-Stemme and Brook Vasstak) // Water: chemistry and ecology. 2013. N 2. P. 109-114.

[30] Klanova J., Matykiewiczova N., Maska Z., Prosek P., Laska K., Klan P. Persistent organic pollutants in soils and sediments from James Ross island, Antarctica // Environ. Pollut. 2008. Vol. 152, N 2. P. 416-423.

[31] Galiulin R.V., Galiulina R.A. Impact zones of persistent organochlorine compounds in the environment // Agrochemistry. 2011. N 3. P. 83-89.

[32] Bobovnikova Ts.I., Virchenko E.P, Malakhov S.T. Pollution of soils and some elements of the balance of organochlorine pesticides in some regions of the Soviet Union // Pollution of the atmosphere, soil and vegetation. Tr. IEM. M.: Gidrometeoizdat, 1980. Vol. 10(86). P. 33-38.

[33] Ivanov A.V., Vasilyev V.V. State of public health in areas of intensive use of pesticides // Hygiene and Sanitation. 2005. N 2. P. 24-27.

[34] Galiulin R.V., Bashkin V.N., Galiulina R.A. Review: Conduct of persistent organic pollutants in the air-plant-soil system // Water Air Soil Pollut. 2002. Vol. 137. P. 179-191.

[35] Galiulin R.V, Galiulina R.A. Persistent organochlorine compounds in the South-Eastern region of the Sea of Azov // Water: chemistry and ecology. 2012. N 10. P. 3-8.

[36] Galiulin R.V., Bashkin V.N. Organochlorinated compounds (PCBs and insecticides) in irrigated agrolandscapes of Russia and Uzbekistan // Water, Air and Soil Pollution. 1996. Vol. 89. P. 247-266.

[37] Ma M., Feng Z., Guan C., Ma Y., Hu H., Li H. DDT, PAH and PCB in sediments from the intertidal zone of the Bohai sea and the Yellow sea // Marine Pollut. 2001. Vol. 42, N 2. P. 132-136.

[38] Fillmann G., Readman J.W., Tolosa I., Bartocci J., Villeneuve J.P., Cattini C., Mee L.D. Persistent organochlorine residues in sediments from Black sea // Marine Pollut. Bul. 2002. Vol. 44, N 12. P. 1426-1434.

[39] Stephen de Mora S., Villeneuve J.P., Sheikoleslami M.R., Cattini C., Tolosa I. Organochlorinated compounds in Caspian sea sediments // Marine Pollut. Bul. 2004. Vol. 48, N 1-2. P. 30-43.

[40] Ostrovskaya E.V., Asaeva K.I., Korshenko A.N., Samsonov D.P., Kolesnikova N.I., Kochetkov A.I., Pantyukhina A.G. Pollution of bottom sediments of the North-Western parts of the Caspian Sea with hydrocarbons and persistent organic pollutants // Geography and geo-ecology. South of Russia: ecology, development. 2014. N 4. P. 129-131.

[41] Amirgaliev N.A. On the assessment of the current ecological and toxicological state of the Kazakhstan sector of the Caspian Sea // Mat. between scientific practical conf. «Agrarian science-agricultural production of Siberia, Mongolia, Kazakhstan and Bulgaria». Krasnoyarsk, 2011. Part 2. P. 305-307.

[42] Klenkin, A.A., Korotkova, L.I., Korpakova, I.G., Kornienko, G.G. Organochlorine pesticides and polychlorinated biphenyls in commercial fish of the Sea of Azov // Vopr. Fish. 2008. Vol. 9, N 2(34). P. 495-502.

[43] Chuiko G.M., Zakonov V.V., Morozova A.A., Brodsky E.S., Shelepchikov A.A., Feshin D.B. Spatial distribution and qualitative composition of polychlorinated biphenyls (PCB) and organochlorine pesticides (OCPs) in bottom sediments and bream (Abramis brama) from the Rybinsk reservoir // Biol. internal waters. 2010. N 2. P. 98-108.

[44] Lukyanova O.N., Boyarov D.D., Chernyaev A.P., Barabanschikov E.I., Aleshko S.A. Organochlorine pesticides in aquatic ecosystems of the Russian Far East // Use and Protection of Natural Resources in Russia. 2007. N 2. P. 31-35.

[45] Lukyanova O.N., Brodsky E.S., Chuyko G.M. Persistent organic pollutants in the bottom sediments of the estuarine zones of the three rivers of Peter the Great Bay (Sea of Japan) // Bulletin of Tyumen State University. 2012. N 12. P. 119-126.

[46] German A.V., Zakonnov V.V., Mamontov A.A. Organochlorine compounds in bottom sediments, benthos and fish of the Volga Rybinsky reach // Water resources. 2010. Vol. 37, N 1. P. 84-88.

[47] Amirgaliev N.A. Hydrochemical indicators and the level of pesticidal pollution of the aquatic environment of the Bukhtarma reservoir // Ecosystem and fish resources of the reservoirs of Kazakhstan. Almaty: Publishing House «Bastau», 1997. P. 176-182.

[48] Amirgaliev N.A., Supiyeva Kh.T. On the level of pesticidal pollution of the ecosystem of the Kapchagai reservoir // Fish resources of water bodies of Kazakhstan and their use. Almaty: Publishing House «Bastau», 1993. P. 83-87.

[49] Amirgaliev N.A., Timirkhanov S.R., Alpeysov Sh.A. Ichtiofauna and Ecology of the Alakol Lake System. Almaty: Bastau, 2006. 367 p.

[50] Amirgaliev N.A., Ismukhanova L.T., Kulbekova R.A. Persistent organic pollutants in the water of the Kapshagay reservoir on the Ili River // Proceedings of the IV international scientific-practical conference «Innovation management and technology in the era of globalization» (10 – January 12, 2017). Dubai, 2017. Vol. 2. P. 68-76.

[51] The plan for fulfilling the obligations of the Republic of Kazakhstan under the Stockholm Convention on Persistent Organic Pollutants for 2015–2028 as of December 30, 2014. Astana, 2014. 76 p.

[52] [Electronic resource] – Access mode: http://www.uzluga.ru/portd/Report+program+001+“Ensuring+activities+authorized+authority+in +area of protection + environment +d/part-9.html Report program 001 «Ensuring the activities of the authorized body in the field of environmental protection» Preparation of the first National Report on Persistent Organic Pollutants to the Secretariat of the Stockholm Convention on POPs. Astana, 2010. 105 p.

[53] Amirgaliev N.A., Turalykova L.T. On the assessment of the water quality of the Alakol lakes system // «Some aspects of hydro-ecological problems of Kazakhstan». Almaty: Kaganat, 2011. P. 166-175.

[54] Amirgaliev N.A. Polychlorinated biphenyls in the aquatic ecosystem of the Ile-Balkhash basin. Almaty: Nurai Print Service, 2016. 192 p.

[55] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[56] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

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ADAPTIVE MODEL OF MUTUAL FINANCIAL INVESTMENT PROCEDURE CONTROL IN CYBERSECURITY SYSTEMS OF SITUATIONAL TRANSPORT CENTERS

Abstract. The article presents a model of searching investment control strategies in cybersecurity systems of situational transport centers. The solution of the problem was considered in the context of the development of the Unified State Information and Communication System of Transport of the Republic of Kazakhstan. The model is a component of the information component of intellectualized decision support systems in the tasks of analyzing various strategies for investing in cybersecurity systems of situational transport centers, in particular for the case of mutual investment in a large innovation project for the modernization of information security systems and cybersecurity systems by several states or companies. A characteristic feature of the model is the possibility of working out specific recommendations choosing their strategies for investment in information technology and cybersecurity systems of the situational transport center. It is based on the consideration of a bilinear dynamic quality game with several terminal surfaces. The difference of such a bilinear dynamic game, from previously considered ones, lies in the fact that the discrete equations, that define the dynamics, can be described with the help of arbitrary coefficients.

The solution of such a game is in the class of positional strategies at all relations of the parameters of the investment process. The constructive method of the solution allows to create an intellectualized decision support system. This makes it possible to optimize management decisions in the investment process for cybersecurity systems of situational transport centers.

There are described the results of computational experiments conducted with the help of the intellectualized decision support system (IDSS) "SSDMI". Considered various relationships between the parameters of the investment process in the cybersecurity systems of the situation center. During the simulation there was confirmed the performance of the model and IDSS SSDMI and its high efficiency.

Keywords: cybersecurity, situational transport center, differential game, optimal investment strategies, hacking and protection, intellectualized decision support system.

Introduction. It's no secret that nowadays one of the priority problems of any business, including transport, is the task of providing information (IS) and cybersecurity (CS) [1, 2]. However, even after setting up cyber protection contours, many transport companies subjectively feel a potential loss to the side of the attack. The constant shortage of temporary, financial and human resources, while ensuring reliable cyber protection, leads to the fact that the problems of IS do not lose their relevance with the time. And it is not a simple task to attract investors for projects in the field of CS [1, 2]. The procedure of investment in innovative projects, for example, in the field of information technology (IT), cybersecurity (CS), and others, is often characterized by a high degree of uncertainty and risk. Therefore, in particular, the landscape of cyberthreats on transport that changed over the past few years [1] had a profound impact on the attitude of many transport companies to the problems of the CS [1, 2]. First of all, this was due to the significant potential vulnerabilities and cyberthreats for information and communication systems (ICS)

of the transport (ICTS), to the occurrence of new classes of cyberattacks, to the widespread use of wireless data transmission technologies, etc. Also in recent decades, there were actively developed navigation systems with the use of GPS, GLONASS, GALILEO, active and passive monitoring and video surveillance systems for vehicles and cargo, new GSM, GSM-R, VSAT technologies, dispatching, situational and logistic management systems, etc. In the conditions of the rapid implementation of digital technologies at the objects of informatization of the transport industry [1, 2] not all investors paid due attention to the problems of the CS of ICTS [1, 2]. However, as well as to the tasks related to the need to review investment strategies caused by the occurrence and timely recognition of cyberthreats for ICTS, which many experts consider to be components of critical information infrastructures of leading industrial states [1, 2].

In order to increase the effectiveness of evaluation various investment projects in the demanded cybersecurity systems (CSS) of various information objects, in particular, in situational transport centers (STC), and subsequent decision-making related to investment, it is necessary to use "intellectualized decision support systems" (IDSS) [3], and, in particular, with elements of self-learning, i.e. adaptivity of the used algorithms.

Filling the IDSS and their individual modules directly responsible for the analysis and solution of specific tasks is carried out by implementation blocks containing programmed algorithms for economic and mathematical models. However, not many IDSS allow to optimize the procedures related to the searching for different variants of strategies in the mutual financial investment of companies in CSS [3, 4]. In this regard, it is important to develop new economic and mathematical models for IDSS, which will adequately describe the real processes of CSS investment, due to the growing level of competition between various firms and corporations on this market.

Literature review and problem statement. In recent years, a large amount of works [4–6] have been devoted to the problem of choosing effective strategies for financial investment in IT and CSS of various information objects.

It should be noted that with the development of computerized systems and IT, there was occurred a separate direction of researches devoted to the application of expert systems [7-9] and decision support systems (DSS, hereinafter IDSS) [10-12] in the tasks of determining rational investment strategies in IT and CSS. Unfortunately, as the analysis of the mentioned publications [11, 12] has shown, the authors did not offer any real recommendations during the search for rational strategies of mutual financial investment in similar spheres of human activity.

Also, as follows from the conclusions [8, 9] and [11, 12], the use of ES and DSS in order to automate procedures for selecting rational strategies for investment control in CSS is not always accompanied by clear recommendations, as the models and algorithms proposed by the authors are affected by a large number of secondary factors and limitations. And besides, as the authors admit themselves [12, 13], the proposed models have no adaptability parameter [8. 11], i.e. require correction even in the case of a slight change in the list of initial parameters and boundary conditions.

The aforementioned caused the problem related to the need to develop new adaptive models for IDSS [13] in the tasks of determining rational strategies for mutual financial investment, especially in the IT and CSS of various information objects.

On the basis of the previous experience and approaches, outlined by the authors in earlier publications on this topic [1, 3, 12-14], and also close in methodology of research publications of external authors [4, 5, 9, 10, 15, 16], we can confirm that a fairly effective approach in solving this class of problems is the use of methods of the differential quality games theory with several terminal surfaces [14-17].

Therefore, the analysis of publications on this subject confirmed the relevance of the problems of further development of adaptive models and corresponding algorithms for IDSS in the tasks of continuous mutual investment in IT and CSS of various information objects. The last is especially important for cases when it is necessary to develop clear recommendations for investors without complex mathematical calculations, shifting most of the calculations to computer programs in IDSS.

Purpose and objectives of the research. The purpose of the work is a model for the module of the intellectualized decision support system during the continuous mutual investment in the cybersecurity systems of the information object, in particular in the IT and CSS of the situational transport center.

In order to achieve the research purpose it is necessary to solve such problems:

- to develop an adaptive model of searching for investment control strategies for various relationships of investment process parameters in information technologies and cybersecurity systems of the information object;

- to perform simulation for different investment strategies, in order to verify the adequacy of the model and to develop rational investment strategies in the CSS of the situational transport center (on the example of such a center in the Republic of Kazakhstan).

Methods and models.

1. Adaptive model of mutual financial investment procedure control in the cybersecurity of the information object. Many transport companies retain the traditional approach of the solution of the CS ICTS tasks. Most solutions are limited by the traditional investments in antivirus software and network protection. This is a fairly simple financial strategy in order to protect the ICTS. Even experienced administrators of information security services are not always ready for the worst scenario during the cyberattacks at ICTS. Nevertheless, nowadays many hackers have mastered sophisticated methods of camouflaging cyberattacks, which can have catastrophic consequences for companies' business. Consequently, the last ones should shift their focus to replacing traditional approaches of CSS financing by changing the financial component of investment strategies to cybersecurity in the direction of detecting and blocking ICTS security systems hacking [18, 19]. Probably, for the customer the financial strategy of investing in integrated systems of information security and cybersecurity will be more profitable. In this case, it will be difficult without foreign investment. Particularly, for large IT projects, for example, such a large-scale one as the creation of the Unified State Information and Communication Transport System of the Republic of Kazakhstan (USICTS RK), see figure 1.

Such a project is caused by the need to integrate the existing ICTS of Kazakhstan into the Eurasian transport network. At the same time, the socioeconomic, technical and technological aspects of the development of the Republic of Kazakhstan, within the concept of the formation of the digital market economy, will significantly affect the subsequent change of the principles of IT functioning in the entire transport industry. The success of such a large-scale project is connected with ensuring the cybersecurity of the USICTS. The basis of the USICTS of the Republic of Kazakhstan should be a single information resource, which is created on the principle of decentralized databases, integrated among themselves by a protected telecommunication environment [9, 20, 21]. Local, regional, as well as ICS of certain transport types will be available to all participants of the transport market, regardless of the transport type and forms of carriers ownership.

Let consider the following situation. An investor from a country where a stronger currency (Val_1) is in monetary circulation, having free capital, is trying to choose the most preferable variants for its investment. In order to do this, he chooses a counterparty, i.e. object for investment his funds, in a country with a weaker currency (Val_2) in use. This object can be, for example - the economy of another country, or the economic region, or, for example, information and communication systems, CS systems, etc. There is an interaction of the investor and his counterparty. During the interaction, they seek to achieve their goals, in particular, to increase their capital and to improve their financial and economic indicators. In the future, without the loss of generality, we assume that the counterparty also seeks to increase its capital. However, non-coinciding interests, non-optimal governance and the presence of uncertainty do not always allow to reach the interaction simultaneously for the both sides.

If this task arises regularly for an investor, then it is appropriate to use IDSS in the decision-making process related to investment. The formalization of the investment process is given under the assumption that the investor is an economic region in one country (REG_1), the counterparty is the economic region (REG_2) in another country.

We will describe the "basic" process – the process of interaction between REG_1 of one country and REG_2 of another country. REG_1, having some free resources (its investment capital), increases them by α_1 times (α_1 – the growth rate of REG_1 resources) and then decides how much of these resources it will invest in active operations. These operations consist in placing resources in the investment projects of REG_1 and debts repayment of REG_1 at that time. We will assume that the same produces are carried out by REG_2 in relation to REG_1. We should note that if REG_2 does not allocate its resources to REG_1, then, as it will follow from the below mentioned, this will be a special case of the variant with

REG_2 and will be performed under the following assumptions: a) REG_1 controls the financial resources x valued in Val_1; b) REG_2 controls the financial resources y valued in Val_2; c) during the interaction, the ratio Val_1 to Val_2 (exchange rate) k_d remains constant. If these assumptions are fulfilled, the interaction proceeds as follows.

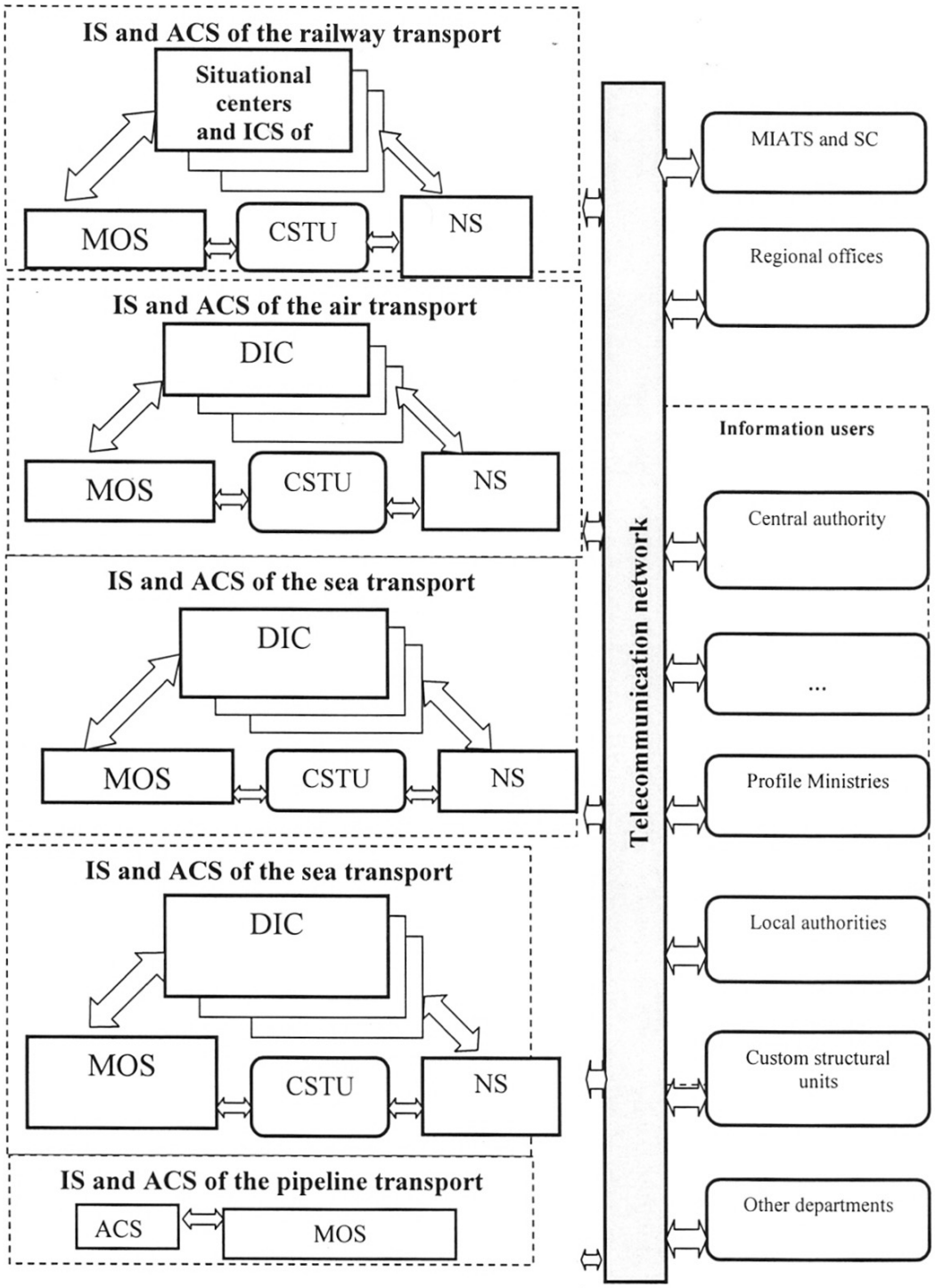

Figure 1 – Organizational and functional structure of the unified state information and communication transport system of the Republic of Kazakhstan:
ACS – an automated control systems; DIC – a departmental information center;
MIATS – the main information and analytical transport center; IS – information systems; CSTU – computerized systems of transport units; MOS – monitoring and observation systems; NS – navigation systems; SC - situational centers

After REG_1 and REG_2, which is a counterparty for REG_1, determined with the share of resources allocated for mutual active operations, mutual debts repayment, resource values, REG_1 and REG_2 will be determined by the following system of discrete equations:

$$x(t+1)=\alpha_1\cdot x(t)+\left[(1-\beta_1(t))\cdot(a_1(t)+r_1(t))-1\right]\cdot u(t)\cdot\alpha_1(t)\cdot x(t)+ \\ +\left[1-(a_2(t)+r_2(t))\cdot(1-\beta_2(t))\right]\cdot v(t)\cdot\alpha_2(t)\cdot\frac{y(t)}{k_d}; \quad (1)$$

$$y(t+1)=\alpha_2\cdot y(t)+\left[(1-\beta_2(t))\cdot(a_2(t)+r_2(t))-1\right]\cdot v(t)\cdot\alpha_2(t)\cdot y(t)+ \\ +\left[1-(a_1(t)+r_1(t))\cdot(1-\beta_1(t))\right]\cdot u(t)\cdot\alpha_1(t)\cdot x(t)\cdot k_d. \quad (2)$$

Therefore, at the moment of time t the value $x(t+1)$ REG_1 (in Val_1) will be equal to the sum of the following components

$\alpha_1(t)\cdot x(t)$, – interest value of $a_1(t)\cdot(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)$ for the invested financial resources of REG_1;

$(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ the value of the invested financial resources of REG_1;

$r_1(t)\cdot(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ the value characterizing the share of the "returned" investment resource of REG_1;

$(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ the investment resource of REG_1 on CSS;

$\left[\left\{(1-r_2(t))\cdot\left(1-\frac{\beta_2(t)}{k_d}\right)\right\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)\right]-$ the value of the "unreturned" asset (investment) of REG_2 (in Val_1);

$\left[\left\{\frac{\beta_2(t)}{k_d}\right\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)\right]-$ the resources for the debt repayment of REG_2 to REG_1;

$u(t)\cdot\beta_1(t)\cdot\alpha_1(t)\cdot x(t)-$ the resource for the debt repayment of REG_1 at the moment of time t to REG_2;

$u(t)\cdot(1-\beta_1(t))\cdot\alpha_1(t)\cdot x(t)-$ the resource of REG_1 for investment in the CSS at the moment of time t;

$\left\{a_2(t)\cdot\left(1-\frac{\beta_2(t)}{k_d}\right)\right\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ interest payment for investment resources of REG_2;

$\left\{\left(1-\frac{\beta_2(t)}{k_d}\right)\right\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ investment resource of REG_2.

Similar components will also be for the expression (2). Therefore, the value $y(t+1)$ (in Val_2) at the moment of time t will be equal to the sum of following components:

$\alpha_2(t)\cdot y(t)$, – interest value of $a_2(t)\cdot(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)$ for the invested financial resources of REG_2;

$(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ the value of the invested financial resources of REG_2;

$r_2(t)\cdot(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ the value characterizing the share of the "returned" investment resource of REG_1 in REG_2;

$(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ the investment resource of REG_2 on CSS;

$(1-r_1(t))\cdot(1-\beta_1(t))\cdot u(t)\cdot k_d(t)\cdot\alpha_1(t)\cdot x(t)-$ the value of the "unreturned" asset (investment) of REG_1 in REG_2;

$u(t)\cdot\beta_1(t)\cdot k_d(t)\cdot\alpha_1(t)\cdot x(t)-$ the resource for the debt repayment of REG_1 to REG_2;

$v(t)\cdot\beta_2(t)\cdot\alpha_2(t)\cdot y(t)-$ the resource for the debt repayment of REG_2 to REG_1 at the moment of time t;

$(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)-$ the resource of REG_2 for investment in the CSS at the moment of time t;

$a_1(t)\cdot(1-\beta_1(t))\cdot k_d(t)\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ interest payment for investment resources of REG_1;

$(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)-$ investment resource of REG_1.

Interaction ends when the variants of the conditions are fulfilled:

1) $x(t+1)\geq 0;\quad y(t+1)\prec 0;\quad$ 2) $x(t+1)\prec 0;\quad y(t+1)\geq 0;$

3) $x(t+1)\prec 0;\quad y(t+1)\prec 0;\quad$ 4) $x(t+1)\geq 0;\quad y(t+1)\geq 0.$

From an economic point of view, these variants are interpreted as follows.

Variant 1. The situation of investment resources (capital) loss of REG_2. REG_1 multiplied its capital by the amount of capital REG_2.

Variant 2. The situation of capital loss of REG_1. REG_2 increased its capital by the amount of capital REG_1.

Variant 3. The situation of capital loss of REG_1 and REG_2 (the default of both subjects of interaction).

Variant 4. The ability of subjects to continue interaction.

There is a question, how to determine the time of possible capital (investment resources) loss according to the information on the initial resources (capital), the exchange rate, the growth rates of REG_1 and REG_2 resources, the interest rates for the allocated capital, the levels of payables and receivables. The toolkit of the multi-step quality games theory [12, 14–17], which allows to determine the areas of possible initial states of resources (capitals) of interacting objects with the following property: if the interaction begins from these states, then at one moment of time the loss of capital is possible both by the one side of the interaction and by the other one, answers the posed question. In order to find such areas there is solved a multi-step quality game with two terminal surfaces, the solution of which is to determine the set of preferences, and also the strategies (control actions) of the parties, using of which make it possible to obtain the outcomes preferred for each side. In this approach, the set of preferences of one side are, in fact, a set of capital loss for the other party. Indeed, for any party of such interaction, the preferred outcome is the preservation of the capital, and undesirable one - its loss. However, it is quite possible that one of the party could act to the other in worst way, that ultimately led the other side to a capital loss. In this case, the set of initial states of the resources of the interacting parties possessing the property that there are strategies (control actions) of one side leading the other side to a state of capital loss, can be called as a set of capital loss for the other party.

We should note that the initial interaction is not limited by the multi-step game model. Similarly, it is possible to simulate interaction that reflects the functioning of several economic regions; it is possible to take into account the incompleteness of information among regions, etc. Therefore, it is possible to use the apparatus of multi-step games for group interaction and for interaction with incomplete information.

In the article, we shall limit ourselves by a simple interaction, which, despite all simplicity, nevertheless allows us to make qualitative conclusions about the financial state of the subjects, depending on the correlation of the parameters of this interaction, and on the possible capital loss of one or the other interaction subject.

The solution of the problem. For convenience of the presentation we will "identify" REG_1 with the player (I), and REG_2 – with the player (II). The above mentioned interaction will be considered within the framework of a multi-step positional game with complete information [12, 14–17]. Within the framework of this scheme, the interaction "generates" two tasks – from the point of view of the first player-ally and from the point of view of the second player-ally. Because of the symmetry it is sufficient to consider one of them, for example, from the point of view of the first player-ally. For this, we will define the pure strategies of the first player-ally. Denote by $T=\{0,1,...\}$ – the discrete set characterizing the region of time parameter change.

Definition. The pure strategy of the first player-ally is the function $u: T \cdot [0,1] \cdot [0,1] \to [0,1]$, that puts the state of information (position) $(t, x(0), y(0))$ the value $u(t, x(0), y(0)): 0 \le u(t, x(0), y(0)) \le 1$.

The pure strategy of the first player-ally is the function (rule) that puts the state of information at the moment of time t the value $u(t, x(0), y(0))$ that determines the value of the resource (capital) of the first player, which he allocated to "invest" the second player. With regard to the knowledge of the opponent player (within the framework of the positional game scheme), no assumptions are made, that is equivalent to the fact that the opponent player chooses his control action $u(t)$ based on any information. After defining the strategies in **task 1**, we need to determine the set of preferences for the first player. Considering that for the description of the proposed approach it is sufficient to confine ourselves with a qualitative description, the set of preferences W_1 of the first player will be given in this way.

$W_1 -$ a set of such initial resources $(x(0), y(0))$ of players that possess such property.

Property: for initial states there is a strategy of the first player, which for any realizations of the strategy of the second player "leads" to one of the moments of time t, the state of the system $(x(t), y(t))$ in such, when the condition (3) will be satisfied. Moreover, the second player does not have a strategy that can "lead" to the fulfillment of the condition (4) at one of the preceding moments of time. The strategy of the first player, having this property, is called optimal. The solution of the **task 1** is to find the set of preferences of the first player and his optimal strategies. Similarly, the problem is posed from the point of view of the second player-ally. Because of the symmetry of the problems statement it is sufficient to confine ourselves with the solution of the **task 1**, because the solution of the **task 2** is exactly the same.

The solution of the **task 1** is found with the help of the tools of the multistep games theory with complete information [12, 14-17, 20, 21], which allows to find the solution of the game for various ratios of game parameters. We give the solution of the game, i.e. sets of preferences W_1 and optimal strategies for the first player.

Let assume that for any moment of time t the following conditions are satisfied: $\alpha_1(t) = \alpha_1; \quad \alpha_2(t) = \alpha_2; \quad \beta_1(t) = \beta_1; \quad \beta_2(t) = \beta_2; \quad r_1(t) = r_1; \quad r_2(t) = r_2$.

Let denote through q_1 & q_1 the following values: $q_1 = (1 - \beta_1) \cdot (a_1 + r_1) - 1$; $q_2 = (1 - \beta_2) \cdot (a_2 + r_2) - 1$.

Four cases are possible:

a) $q_1 \ge 0; \quad q_2 \ge 0;$ *b*) $q_1 \prec 0; \quad q_2 \prec 0;$ *c*) $q_1 \succ 0; \quad q_2 \le 0;$ *d*) $q_1 \le 0; \quad q_2 \succ 0.$

In addition, it is necessary to take into account that a different ratio of growth rates α_1, α_2 is possible, namely, it can be either $\alpha_1 \succ \alpha_2$ or $\alpha_1 \le \alpha_2$.

In **case a)** and $\alpha_1 \succ \alpha_2$ there are a finite number of set of preferences W_1^i for the first player-ally with the following property.

Property: if $(x(0), y(0)) \in W_1^i$, then the first player in i steps can get the condition (3), no matter how the second player acts. Moreover, the second player has a strategy that does not allow the first player to get the condition (3) in less number of steps. In this case, we write W_1^i in following way:

$$W_1^i = \{(x(0), y(0)): k(i-1) \cdot x(0) \le y(0) \prec k(i) \cdot x(0)\}, \tag{3}$$

where $k(i) = \left(\frac{\alpha_1}{\alpha_2}\right) \cdot \left(\frac{q_1 + q_1 \cdot k(i-1) + k(i-1)}{1 + q_2 + q_2 \cdot k(i-1)}\right), \quad k(0) = 0;$

$i = 1, \ldots, k^* - 1; \quad k^*: k(k^*) \succ \frac{q_1}{q_2}, \quad k(k^* - 1) \le q_1 / q_2,$

(such k^* exists).

The set $W_1^i \quad (i = k^*)$:

$$W_1^i = \{(x(0), y(0)) : k \cdot (k^* - 1) \cdot x(0) \le y(0) \prec (q_1 / q_2) \cdot x(0)\}. \tag{4}$$

The combination of sets W_1^i will determine the set of preferences of the first player W_1 , i.e.:

$$W_1 = \{(x(0), y(0)) : y(0) \le (q_1 / q_2) \cdot x(0)\}. \tag{5}$$

And from any state $(x(0), y(0))$ of this set the first player can reach the condition (3) in a finite number of steps (no more than k^*).

In **case a)** and $\alpha_1 \le \alpha_2$ there are countably number of set of preferences W_1^i of the first player-ally with the following property.

Property: if $(x(0), y(0)) \in W_1^i$, then the first player in i steps can get the condition (3), no matter how the second player acts. Moreover, the second player has a strategy that does not allow the first player to get the condition (3) in less number of steps.

We write the set W_1^i in following way:

$$W_1^i = \{(x(0), y(0)) : k(i-1) \cdot x(0) \le y(0) \prec k(i) \cdot x(0)\}, \tag{6}$$

where $k(i) = \left(\frac{\alpha_1}{\alpha_2}\right) \cdot \left(\frac{q_1 + q_1 \cdot k(i-1) + k(i-1)}{1 + q_2 + q_2 \cdot k(i-1)}\right), \quad k(0) = 0.$

In this case we will write W_1 as follows:

$$W_1 = \{(x(0), y(0)) : y(0) \le (q_*) \cdot x(0)\}, \tag{7}$$

where $q_* : q_* = \left(\frac{\alpha_1}{\alpha_2}\right) \cdot \left(\frac{q_1 + q_1 \cdot q_* + q_*}{1 + q_2 + q_2 \cdot q_*}\right).$

The optimal strategy of the first player in these cases is to "allocate" all of the capital to investments, if the resources $(x(0), y(0))$ belong to the first player's set of preferences.

Quite symmetrically, in these cases, there are found the set of preferences and the optimal strategy of the second player.

In **case b)** the whole set R_+^2 is preferable for both the first and second players. In any strategy, players will be able to continue the interaction.

In **case c)** and at the verity of the inequality $\left(\frac{\alpha_1}{\alpha_2}\right) \cdot (q_1 + 1) \ge 1,$, the set of preferences for the first player W_1 is all admissible initial resources, i.e. R_+^2. A set of preferences W_2 does not exist in this case. The optimal strategy for the first player is to invest all available resources in investments.

In **case c)** and at the verity of the inequality $\left(\frac{\alpha_1}{\alpha_2}\right) \cdot (q_1 + 1) \prec 1,$ the set of preferences for the first player W_1 are determined in following way:

$$W_1 = \{(x(0), y(0)) : y(0) \le (q_*) \cdot x(0)\}, \tag{8}$$

where $q_* : q_* = \left(\frac{\alpha_1}{\alpha_2}\right) \cdot \left(\frac{q_1}{\left(1 - (q_1 + 1) \cdot \left(\alpha_1 / \alpha_2\right)\right)}\right).$

In this case, there is a countable amount of set of preferences W_1^i for the first player-ally with the property if $(x(0), y(0)) \in W_1^i$, then the first player in i steps can get the condition (3), no matter how the

second player acts. Moreover, the second player has a strategy that does not allow the first player to get the condition (3) in less number of steps.

We write the set W_1^i in following way:

$$W_1^i = \{(x(0), y(0)) : k(i-1)\cdot x(0) \le y(0) \prec k(i)\cdot x(0)\}, \quad (9)$$

where $k(i) = \left(\frac{\alpha_1}{\alpha_2}\right)\cdot(q_1 + q_1\cdot k(i-1) + k(i-1)), \quad k(0) = \left(\frac{\alpha_1}{\alpha_2}\right)\cdot q_1.$

The optimal strategy for the first player is to invest all available resources in investments.

A set of preferences W_2 does not exist in this case.

In **case d)** the situation is symmetric to the **case c)**, i.e. a set of preferences W_1 does not exist. The set of preferences W_2 is determined in a symmetric manner with respect to the set of preferences W_1 for the **case c).**

All cases of correlation of interaction parameters are considered. Symmetrically solved the **task 2** from the point of view of the second player-ally.

As it was noted, the problem from the point of view of the second player-ally is solved similarly. And the areas of preferences from the point of view of the second player are "adjacent" to the areas of preference of the first player. These areas are divided among themselves by equilibrium beams (EQB) [12, 14, 17, 22]. The equilibrium beams have the following property: if a pair of states $(x(0), y(0))$ belongs to the EQB, then players have strategies that allow them to be on the EQB for all subsequent moments of time. Solving the tasks by the proposed game methods in the (x, y) variables space we can find EQB, that is, if the interaction starts from these states, then the players have strategies that allow them to stay on EQB. It means that, at the given $(x(0), y(0))$ it is possible to find the ratio of the interaction parameters for which the pair $(x(t), y(t))$ will be located on the EQB.

If the initial states (resources) are not on the beam of equilibrium interaction, then we can try to change the interaction parameters in such a way when the initial resources are on the EQB. This will allow the parties to continue their interaction for as long as they like.

It should be noted that there are possible situations where the interaction parameters have changed. Then, it is possible to carry out the above mentioned procedure with new parameters and to find new optimal strategies for interaction between the parties, that is, the proposed interaction control scheme is adaptive.

Remark 1. It is easy to see that a more "strong" currency influences the "increase" of preference zones (comparison by inclusion of sets) and the "decrease" of investor risk zones from an economy with a "stronger" currency, and vice versa. It means that an investor with a "weaker" currency should leave those areas of financial resources that become affected by the risk of capital loss due to the "weakening" of the currency of the investor's country.

Remark 2. The considered example of the simplest interaction allows to make the following conclusion that in the space of initial resources there are areas of preference for players. Therefore, if the resources are in the player's preference area, then it is disadvantageous for this player to avoid interaction with the other player, because the other player can change the resource ratio at the absence of interaction as a result of autonomous operation (for example, using the advantage of technology, i.e. in the case if its growth rate is greater) and thereby go to the set "preferred" for him. And then, having already entered into interaction, gain an advantage in this interaction and "lead" another player to a capital loss.

Experiment. The quantitative analysis of the parameters, obtained in the process of searching for rational financing strategies in the systems of cybersecurity of transport companies on the example of large investment projects in Kazakhstan and Ukraine, was carried out by simulation modeling in the Matlab/Simulink environment. For this purpose, there was constructed a corresponding simulation model that contains the blocks of equations (1) and (2) given in point 4, see figure 2. This simulation model was compiled on the basis of the standard blocks of the Matlab/Simulink environment. This made it possible to obtain the required parameters during the computational experiments, see figure 3 and 4.

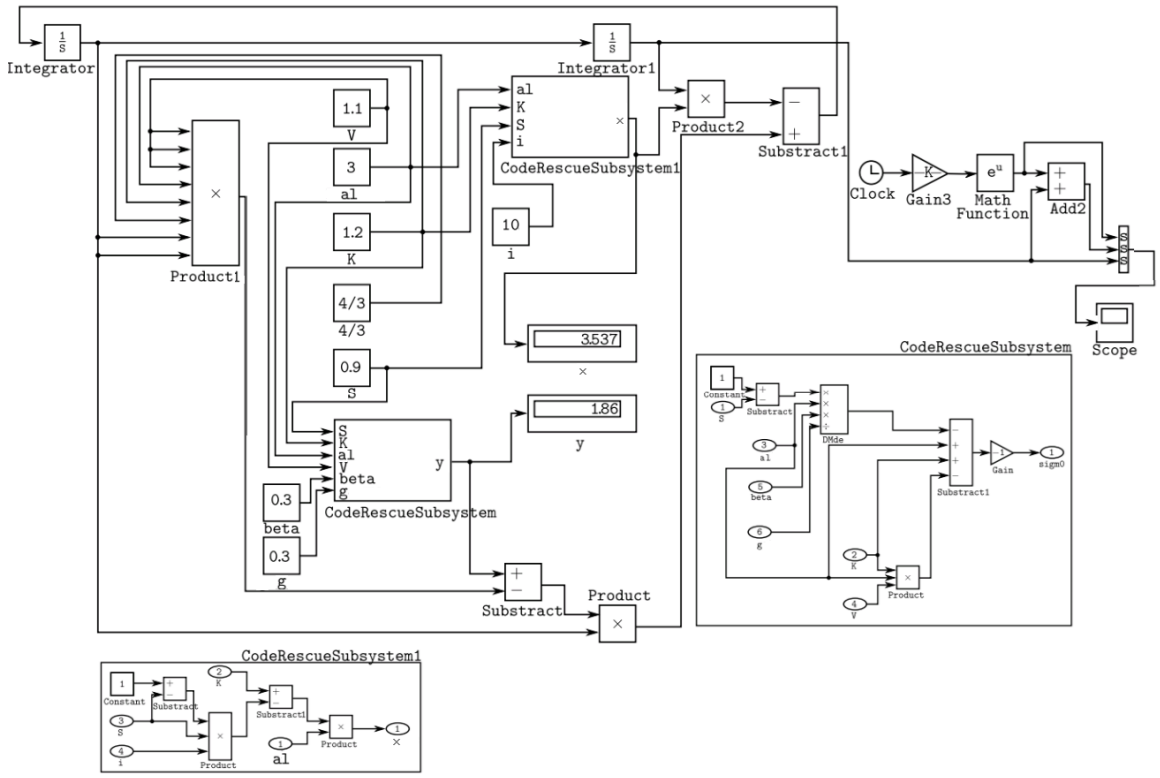

Figure 2 – Simulation model based on equations (1) and (2)

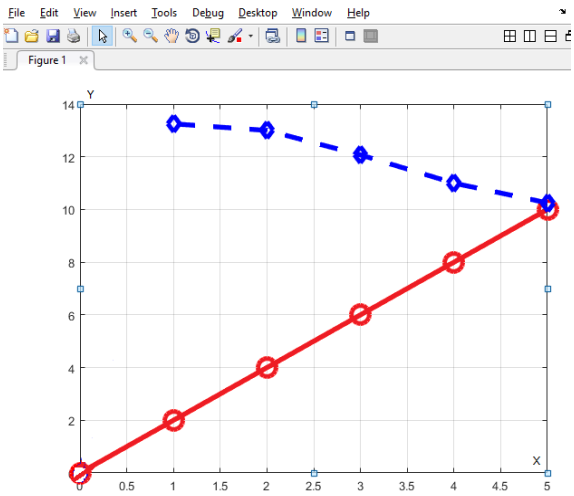

Figure 3 – Example 1 of the results of a computational experiment in the Matlab/Simulink environment

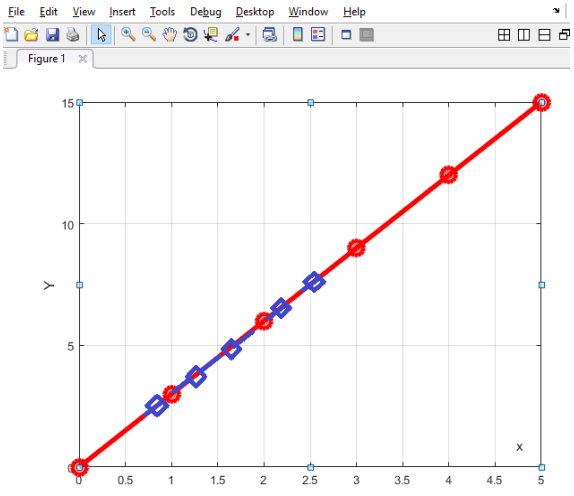

Figure 4 – Example 2 of the results of a computational experiment in the Matlab/Simulink environment

On the basis of the proposed model of continuous mutual investment, there was implemented the program module IDSS "SSDMI", see figure 5. The module is implemented in Delphi language.

During the analysis of the IDSS "SSDMI" module operation, the correctness of the algorithm execution was monitored.

The IDSS "SSDMI" module can be used as an independent software product, and as an auxiliary unit of the decision support system "DMSSCIS", which, in particular, allows to assess the risks of investment in information security systems of large enterprises [15, 16].

On the graphs of figures 3 and 4, the x-axis means “mln, $” (in our case Val_1). On figure 3 the tangent of the angle slope is "2". That is, the equilibrium beam is determined by the relation $y = q_* \cdot x$,

$q_* = 2.0$. On figure 4 the tangent of the angle slope is "3". The y-axis means "mln. hryvnia" (Val_2, for the case of the national currency of Ukraine). On figures 3 and 4, the investors' movement trajectory is shown by a blue dotted line with blue markers (rhombuses). The equilibrium beams are shown on figures 3 and 4 by a red solid line with red round markers. Similar calculations can be made for the case when tenge (Kazakhstan) is used as the currency.

On figure 5, the tangent of the angle slope is "3.5". That is, the equilibrium beam is determined by the relation $y = q_* \cdot x, \quad q_* = 3.5$. The area, highlighted in blue, corresponds to W_1. The area marked with a light yellow color, corresponds to W_2. The trajectory of investors' movement (shown by a red line with blue markers in the W_1 area), determined using the simulation model shown in figure 2, as well as using IDSS SSDMI, (x - financial resource of the first investor, y - financial resource of the second investor).

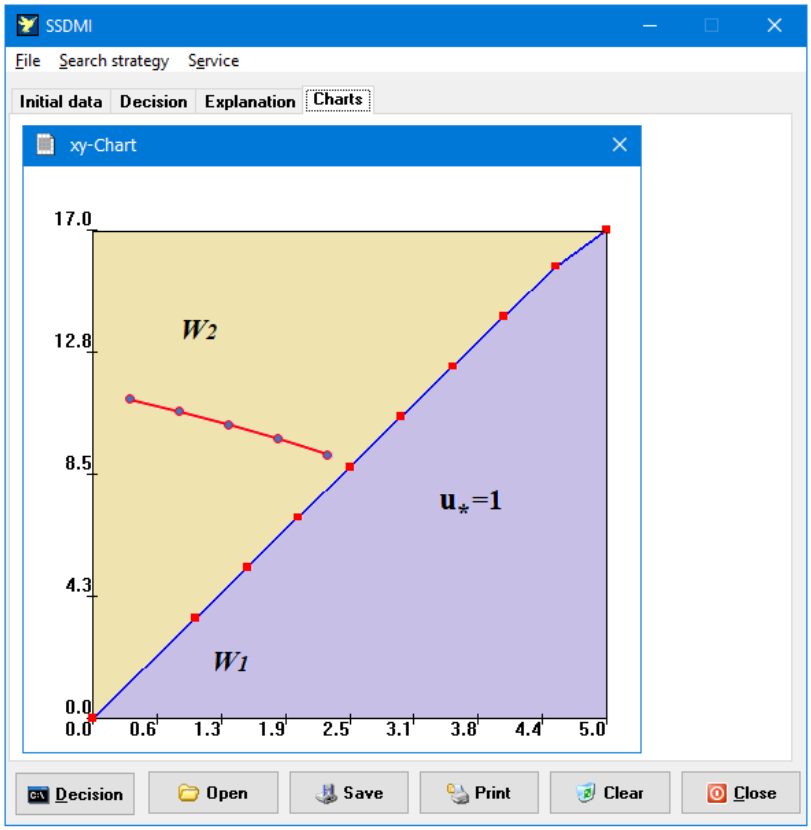

Figure 5 – The results of the operation of IDSS "SSDMI" for the selection of strategies for mutual investment in the cybersecurity systems of the situational transport center

The results obtained in the graph demonstrate the effectiveness of the proposed approach. During the testing of the program "SSDMI" there was established the correctness of the received results.

Discussion. The considered model for the interaction procedure, both at the micro and macro levels, is the process of prediction the results of investment in CSS of ICTS. The Figure 3 corresponds to an simulation experiment in which the second player, using the non-optimal behavior of the first player at the initial moment of time, achieves the case when he "brings" the state of the system to his "own" terminal surface. The Figure 4 corresponds to an simulation experiment in which the initial state of the system is on an equilibrium beam. And the players, applying their optimal strategies, "move" along this beam. This "satisfies" both players simultaneously. The Figure 4 illustrates the "stability" of the system. This corresponds to a situation where, at small deviations in choosing the implementation of the optimal strategy by the first player (see the dotted line), he will reach his goal, but somewhat later. The figure 5 shows the acceptable accuracy of the IDSS "SSDMI" program module in relation to the results of computational experiments in the Matlab/Simulink environment. The discrepancy does not exceed 3-7%. Unfortunately,

the predicted data obtained not always using the IDSS "SSDMI" coincided with the actual data. At this stage of development of our model, this circumstance is a definite disadvantage of the proposed approach. By increasing the amount of variants for financial strategies by the protection side and the amount of computational experiments we can reduce discrepancies. In particular, due to wider use of information technologies for data mining and preliminary expert evaluation of financial protection strategies for ICTS and USITS RK. This will eventually allow us to improve the toolkit for prediction investment processes in CSS.

Comparison of the results of our computational experiments with the data of other authors [6-11, 15, 16] made it possible to conclude that the approach outlined in the article is acceptable. Therefore, the proposed toolkit will allow the participants of the investment process in CSS of ICTS to improve significantly the performance indicators of their activities. In addition, the joint use of software products such as IDSS "SSDMI" and an adaptive expert system for the recognition of cyberthreats (described in the works of the authors [20, 21, 23]) will allow investors not only at the stage of initial analysis of the project, but at the modernization of existing systems of cybersecurity, in particular, for critical computer infrastructures, to build effectively a forward-looking policy in the field of financing of cyber security systems, taking into account the trend towards increasing the amount of threats for their ICS.

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Conclusions. There is proposed a model of searching for investment control strategies in the cybersecurity systems of the situation transport centers in the conditions of active development of the Unified State Information and Communication Transport System of the Republic of Kazakhstan. There were considered different ratios of investment process parameters in CSS

The model is a component of the information component of intellectualized decision support systems in the tasks of analyzing various strategies for investment in cybersecurity systems for situational transport centers, in particular for the case of mutual investment in a major innovation project for the modernization of information security systems and cybersecurity systems by several states or companies. The model is based on the consideration of a bilinear dynamic quality game with several terminal surfaces. The peculiarity of the model lies in the fact that the discrete equations, governing the dynamics of the game, can be described with the help of random coefficients. This made it possible to extend the class of the solved problems. The constructive method of solution allowed to create a module of the intellectualized decision support system. This allows to optimize control decisions in the investment process for cybersecurity systems of situational transport centers.

There are described the results of computational experiments conducted in the Matlab/Simulink environment, as well as with the help of Intellectualized Decision Support System (IDSS) "SSDMI". There were considered various relationships between the parameters of the investment process in the cybersecurity systems of the situation center. The operability of the model and IDSS "SSDMI" and its high efficiency was confirmed.

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КӨЛІК ОРТАЛЫҚТАРЫ ЖАҒДАЙЫНЫҢ КИБЕРҚАУІПСІЗДІК ЖҮЙЕЛЕРІНЕ ӨЗАРА ҚАРЖЫ ИНВЕСТИЦИЯЛАРЫН РӘСІМДЕУДІҢ БЕЙІМДЕЛГЕН МОДЕЛІ

Аннотация. Мақалада көлік орталықтары жағдайының киберқауіпсіздік жүйелерінде инвестициялық басқару стратегиясын табудың үлгісі келтірілген. Мәселені шешу Қазақстан Республикасының тасымалдау Бірыңғай мемлекеттік ақпараттық-коммуникациялық жүйесін дамыту контексінде қаралды. Модель көлік орталықтары жағдайының киберқауіпсіздік жүйелеріне инвестициялаудың әртүрлі стратегияларын талдау міндеттерінде интеллектуалды шешімдерді қолдау жүйелерінің ақпараттық компонентінің құрамдас бөлігі болып табылады, атап айтқанда бірнеше мемлекет немесе компаниялардың ақпараттық қауіпсіздік жүйелерін және киберқауіпсіздік жүйелерін жаңғыртуға арналған ірі инновациялық жобаға өзара инвестициялау жағдайында. Моделдің тән ерекшелігі – ақпараттық-технологиялық және көлік орталығы жағдайының кибер-

қауіпсіздік жүйелерін инвестициялау стратегиясын таңдау кезінде нақты ұсыныстар әзірлеу мүмкіндігі болып табылады. Ол бірнеше терминал беттерімен билинейлі динамикалық сапалық ойын қарауға негізделген. Бұрын қарастырылғандардан айырмашылығы мұндай билинейлі динамикалық ойын арасындағы динамиканы анықтайтын дискретті теңдеулер ерікті коэффициенттер көмегімен сипатталуы мүмкін.

Мұндай ойынның шешімі инвестициялық процестің параметрлерінің барлық қатынастары үшін позициялық стратегиялар класында орналасады. Шешімнің конструктивтік әдісі зияткерлік шешімдерді қолдау жүйесін жасауға мүмкіндік береді. Бұл көлік орталықтары жағдайының киберқауіпсіздік жүйесі үшін инвестициялық процесте басқару шешімдерін оңтайландыруға мүмкіндік береді.

«SSDMI» интеллектуалды шешімдерді қолдау жүйесінің (ИШҚЖ) көмегімен жүргізілген есептік эксперименттердің нәтижелері сипатталған. Оқиғалар орталығының киберқауіпсіздік жүйелеріндегі инвестициялық процестің параметрлері арасындағы түрлі қатынастар қарастырылады. Имитациялық модельдеу барысында ISPPR SSDMI моделінің жұмыс істеу мүмкіндігі және оның жоғары тиімділігі расталды.

Түйін сөздер: киберқауіпсіздік, көлік орталығы жағдайы, дифференциалды ойын, оңтайлы инвестициялық стратегия, бұзу және қорғаныс, зияткерлік шешімдерді қолдау жүйесі.

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АДАПТИВНАЯ МОДЕЛЬ УПРАВЛЕНИЯ ПРОЦЕДУРОЙ ВЗАИМНОГО ФИНАНСОВОГО ИНВЕСТИРОВАНИЯ В СИСТЕМЫ КИБЕРБЕЗОПАСНОСТИ СИТУАЦИОННЫХ ЦЕНТРОВ ТРАНСПОРТА

Аннотация. В статье представлена модель для нахождения стратегий управления инвестированием в системы кибербезопасности ситуационных центров транспорта. Решение задачи рассмотрено в контексте развития Единой государственной информационно-коммуникационной системы транспорта Республики Казахстан. Модель является компонентой информационной составляющей интеллектуализированных систем поддержки принятия решений в задачах анализа различных стратегий инвестирования в системы кибербезопасности ситуационных центров транспорта, в частности для случая взаимного инвестирования в крупный инновационный проект по модернизации систем защиты информационных систем и систем кибербезопасности со стороны нескольких государств или компаний. Характерной чертой модели является возможность наработки конкретных рекомендаций при выборе своих стратегий инвестирования в информационные технологии и системы кибербезопасности ситуационного центра транспорта. Она базируется на рассмотрении билинейной динамической игры качества с несколькими терминальными поверхностями. Отличие такой билинейной динамической игры, от ранее рассмотренных, заключается в том, что дискретные уравнения, задающие динамику, могут описываться с помощью произвольных коэффициентов.

Решение такой игры находится в классе позиционных стратегий при всех соотношениях параметров инвестиционного процесса. Конструктивный метод решения позволяет создать интеллектуализированную систему поддержки принятия решений. Это дает возможность оптимизировать управленческие решения в инвестиционном процессе для систем кибербезопасности ситуационных центров транспорта.

Описаны результаты вычислительных экспериментов, проведенных с помощью интеллектуализированной системы поддержки принятия решений (ИСППР) «SSDMI». Рассмотрены различные соотношения параметров инвестиционного процесса в системы кибербезопасности ситуационного центра. В ходе имитационного моделирования подтверждена работоспособность модели и ИСППР «SSDMI» и ее высокая эффективность.

Ключевые слова: кибербезопасность, ситуационный центр транспорта, дифференциальная игра, оптимальные стратегии инвестирования, взлом и защита, интеллектуализированная система поддержки решений.

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REFERENCES

[1] Lakhno V.A., Petrov A.S., Hrabariev A.V., Ivanchenko Y.V., Beketova G.S. Improving of information transport security under the conditions of destructive influence on the information-communication // Journal of theoretical and applied information technology. 2016. Vol. 89, Iss. 2. P. 352-361. doi: http://ijact.org/volume6issue4/IJ0640002.pdf

[2] Al Hadidi M.M. Intelligent Systems for Monitoring and Recognition of Cyber Attacks on Information and Communication Systems of Transport // International Review on Computers and Software (IRECOS). 2016. 11(12). P. 1167-1177. doi: 10.15866/irecos.v11i12.9108

[3] Lakhno V.A., Kravchuk P.U., Pleskach V.L., Stepanenko O.P., Tishchenko R.V., Chernyshov V.A. Applying the functional effectiveness information index in cybersecurity adaptive expert system of information and communication transport systems // Journal of Theoretical and Applied Information Technology. 2017. 95(8). P. 1705-1714. https://elibrary.ru/item.asp?id=31039373

[4] Manshaei M.H., Zhu Q., Alpcan T. et al. Game theory meets network security and privacy // ACM Computing Surveys. 2013. Vol. 45, N 3. P. 1-39. doi: 10.1145/2480741.2480742

[5] Grossklags J., Christin N., Chuang J. Secure or insure?: a game-theoretic analysis of information security games // 17th international conference on World Wide Web, Beijing, China, 21–25 April 2008: proceedings. New York, ACM, 2008. P. 209-218. doi: 10.1145/1367497.1367526

[6] Cavusoglu H., Mishra B., Raghunathan S. A model for evaluating IT security investments // Communications of the ACM. 2004. Vol. 47, N 7. P. 87-92. https://dl.acm.org/citation.cfm?id=1005828

[7] Gamal M.M., Hasan B., Hegazy A.F. A Security Analysis Framework Powered by an Expert System // International Journal of Computer Science and Security (IJCSS). 2011. Vol. 4, N 6. P. 505-527. http://www.cscjournals.org/library/manuscriptinfo.php?mc=IJCSS-370

[8] Chang Li-Yun, Lee Zne-Jung. Applying fuzzy expert system to information security risk Assessment – A case study on an attendance system, International Conference on Fuzzy Theory and Its Applications (iFUZZY). 2013. P. 346-351. https://ieeexplore.ieee.org/document/6825462/

[9] Kanatov M., Atymtayeva L., Yagaliyeva B. Expert systems for information security management and audit, Implementation phase issues, Soft Computing and Intelligent Systems (SCIS) // Joint 7th International Conference on and Advanced Intelligent Systems (ISIS). 2014. P. 896-900. doi: 10.1109/scis-isis.2014.7044702

[10] Fielder A., Panaousis E., Malacaria P. et al. Decision support approaches for cyber security investment // Decision Support Systems. 2016. Vol. 86. P. 13-23. doi: org/10.1016/j.dss.2016.02.012

[11] Meland P.H., Tondel I.A., Solhaug B. Mitigating risk with cyberinsurance // IEEE Security & Privacy. 2015. N 13(6). P. 38-43. doi: 10.1109/MSP.2015.137

[12] Lakhno V., Malyukov V., Gerasymchuk N. et al. Development of the decision making support system to control a procedure of financial investment // Eastern-European Journal of Enterprise Technologies. 2017. Vol. 6, N 3. P. 24-41. doi: 10.15587/1729-4061.2017.119259

[13] Lakhno V. A. Development of a support system for managing the cyber security // Radio Electronics, Computer Science, Control. 2017. N 2. P. 109-116. DOI: 10.15588/1607-3274-2017-2-12

[14] Malyukov V.P. A differential game of quality for two groups of objects // Journal of Applied Mathematics and Mechanics. 1991. Vol. 55, N 5. P. 596-606. doi: 10.1016/0021-8928(91)90106-5

[15] Fielder A., Panaousis E., Malacaria P. et al. Game theory meets information security management // IFIP International Information Security Conference, Marrakech, Morroco, 2–4 June 2014: proceedings. Berlin, Springer, 2014. P. 15-29. doi: 10.1007/978-3-642-55415-5_2

[16] Gao X., ZhongW., MeiS. A game-theoretic analysis of information sharing and security investment for complementary firms // Journal of the Operational Research Society. 2014. Vol. 65, N 11. P. 1682-1691. doi: 10.1057/jors.2013.13

[17] Malyukov V.P. Discrete-approximation method for solving a bilinear differential game // Cybernetics and Systems Analysis. 1993. Vol. 29, N 6. P. 879-888. doi: 10.1007/bf01122741

[18] Smeraldi F., Malacaria P. How to spend it: optimal investment for cyber security // 1st International Workshop on Agents and CyberSecurity. Paris, France, 06–08 May 2014: proceedings. New York: ACM, 2014. P. 8. doi: 10.1145/2602945.2602952

[19] Tosh D. K., Molloy M., Sengupta S. et al. Cyber-investment and cyber-information exchange decision modeling, High Performance Computing and Communications IEEE // 7th International Symposium on Cyberspace Safety and Security (CSS). New York, 24–26 August 2015: proceedings. New York: IEEE, 2015. P. 1219-1224. doi: 10.1109/HPCC

[20] Akhmetov B., Lakhno V., Boiko Y., Mishchenko A. Designing a decision support system for the weakly formalized problems in the provision of cybersecurity // Eastern-European Journal of Enterprise Technologies. 2017. Vol. 1(2(85)). P. 4-15.

[21] Lakhno V., Malyukov V., Domrachev V., Stepanenko O., Kramarov O. Development of a system for the detection of cyber attacks based on the clustering and formation of reference deviations of attributes // Eastern-European Journal of Enterprise Technologies. 2017. Vol. 3(9(87)). P. 43-52. http://journals.uran.ua/eejet/article/view/119259

[22] Akhmetov B.B., et al. The choice of protection strategies during the bilinear quality game on cyber security financing // Bulletin of the National academy of sciences of the Republic of Kazakhstan. 2018. Vol. 3. P. 6-14. http://nauka-nanrk.kz/ru/BA_03_2018BD.pdf

[23] Akhmetov B., Lakhno V., Akhmetov B., Alimseitova Z. Development of Sectoral Intellectualized Expert Systems and Decision Making Support Systems in Cybersecurity // In: Silhavy R., Silhavy P., Prokopova Z. (eds). Intelligent Systems in Cybernetics and Automation Control Theory. CoMeSySo 2018. Advances in Intelligent Systems and Computing. Vol. 860. P. 162-171. Springer, Cham. 2018. https://link.springer.com/chapter/10.1007%2F978-3-030-00184-1_15

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TECHNOLOGY AND PROSPECTS OF USING SOLAR ENERGY

Abstract. This article deals with the effective use of solar energy and presents a comparative analysis of different ways of converting solar energy into electrical. Solar energy is the kinetic energy of radiation (sunlight), formed as a result of reactions inside the Sun, its reserves are practically inexhaustible. In natural ecosystems, only a small fraction of solar energy is captured and stored as potential energy of organic matter. Its decomposition meets the energy needs of all other components of ecosystems. Regardless of whether we use solar energy or not, it will not affect the energy balance of the Earth and the state of the biosphere. The main novelty of this work is the introduction of redirecting surfaces which has not been previously used by the solar energy industry. These designs help to distribute light evenly over the surface of the solar cell and do not lead to overheating of the system. They also contribute to a significant increase in its effectiveness. The inspiration for this project has been caused by the recently introduced technology of windows. This window technology is capable to redirect sunlight and provide a high-quality lighting of residential premises. The idea of this technology is based on the achievements of micro-optics using uneven surfaces. The light that passes through the window changes its direction and illuminates the ceiling, which in turn helps to avoid direct contact with the human eye.

Keywords: collector of solar rays, solar system, heat exchanger, energy source.

Introduction. Over the past decades, interest in non-traditional and renewable energy sources has increased significantly and continues to increase, because they areunlimited in many respects. The hydrocarbon fuel supplies become less reliable and more expensive, so these non-traditional sources become more attractive and more economical. The increase in oil and gas prices was the main reason why people started to pay their attention again to water, wind and Sun.

The potential of energy based on direct solar radiation is extremely high.

Using only 0.0005% of the Sun's energy it is possible to meet all the current needsfor energy in the world, and using 0.5% of the Sun's energy we wouldbe able to cover all the demand forenergy in the future.

It is estimated that a small percentage of solar energy is sufficient to ensure transport, industry and household needs not only now, but also in the foreseeable future [1]. Moreover, regardless of whether we use solar energy or not, it will not affect the energy balance of the Earth and the state of the biosphere.

However, the sun's rays fall on the surface of the Earth, never reaching a special intensity. Therefore, it is necessary to catch the energy of the sun rays on a relatively large area, concentrate the energy and turn it into a form that can be used for industrial, domestic and transport needs [2]. In addition, it is necessary to find the way how to store solar energy in order to maintain energy supply at night and on cloudy days. These difficulties and the required costs for overcoming the problem make people think that this energy resource is impractical. However, in many cases the problem is exaggerated. It is important to find the way how to use the solar energy with minimal or even zero cost [3]. As technologies improve and traditional energy resources become more expensive, this energy will find new applications.

Currently, the electricity voltage does not match the pure sine wave and has distortion, that occur when using semiconductor converters. Therefore, solar inverters power plants must be adapted to the mains. The use of microprocessor-based inverter control is necessary for a solar power station, which converts solar energy into electricity. It should be noted, what is a microprocessor control system inverter instantly reacts to changes in mains voltage, excluding emergency conditions. At the same time, solar cells persist and takes place maximum electrical conversion solar power in the mains [4].

When creating information systems for complex object modeling of solar power plant processes based on various methods and algorithms, the most common modern software products are used. The need to process large amounts of information requires the development of new intelligent technologies based on various modern approaches [5].

Current systems:

Today, there are two main large-scale methods of solar energy conversion:

1. Photoelectric converters (PhEC) are semiconductor devices that directly convert solar energy into electricity. This method is based on the phenomenon of photoelectric effect discovered in the far twentieth century by Albert Einstein. The conversion of sunlight into electricity occurs in solar cells made of semiconductor material, such as silicon, which under the influence of sunlight produces an electric current. By connecting solar cells into modules, and those, in turn, with each other, it is possible to build large photoelectric plants. The efficiency of such photoelectric plants is currently about 30%. The biggest model of such construction, "Aqua Caliente Solar Project" is in Arizona, USA. Its capacity reaches approximately 400 mW.

This conversion method consumes only that part of the solar energy that gets directly to the surface of the photoelectric cell. This is one of the main drawbacks of this method. To use it more effective, there is a need to focus sunlight [6]. This idea is widely used in solar structures, which are described below.

2. Solar power plants (SPP) are solar installations, using highly concentrated solar radiation as energy to drive thermal and other machines (steam, gas turbine, thermoelectric, etc.). The basis of this design is a system of mirrors concentrating sunlight [7].

One of the largest focusing solar installations "Mojave Desert California" is located in the United States of America. Its capacity is about 350 MW, which is enough to supply electricity to one large city. However, such systems also have significant drawbacks. These disadvantages are the need to install additional elements to convert solar energy, which inevitably leads to some financial costs and huge energy losses in the conversion process.

Concentrated photoelectricity:

Taking into account the advantages and disadvantages of the structures described above, a new system based on the concentration of sunlight on photoelectric cells with help of parabolic mirrors was proposed in the 1970s.

Based on the property of the parabolic mirror, the reflected light is concentrated on the surface of the solar cell, which can significantly reduce the cost of its production. However, this design has two significant drawbacks.

1 - The light is focused on the solar cell and spreads unevenly across its surface, which leads to a decrease in the efficiency of the system.

2 - Due to the concentration of a huge amount of light, the surface temperature of the solar cell increases significantly, which also leads to a decrease in the efficiency of the design [8].

In view of these drawbacks, there is a need for a modern system in which the redirected light is distributed evenly over the solar cell surface and would be in the amount that would not lead to overheating of the structure. The main idea of this project is to improve these drawbacks.

The main novelty of this work is the introduction of redirecting surfaces which has not been previously used by the solar energy industry. These designs make it possible to distribute light evenly over the surface of the solar cell and do not lead to overheating of the system. They also contribute to a significant increase in their effectiveness.

The inspiration for this project has been caused by the recently introduced technology of windows. This window technology is capable to redirect the sunlight and provide high-quality lighting of residential premises. The idea of this technology is based on the achievements of micro-optics using uneven surfaces [9]. The light that passes through the window changes its direction and illuminates the ceiling, which in

turn helps to avoid direct contact with the human eye. The glass used in such a window has a rough surface, which causes the redirection of light.

A detailed description of the light redirection process is shown in figure 1 below.

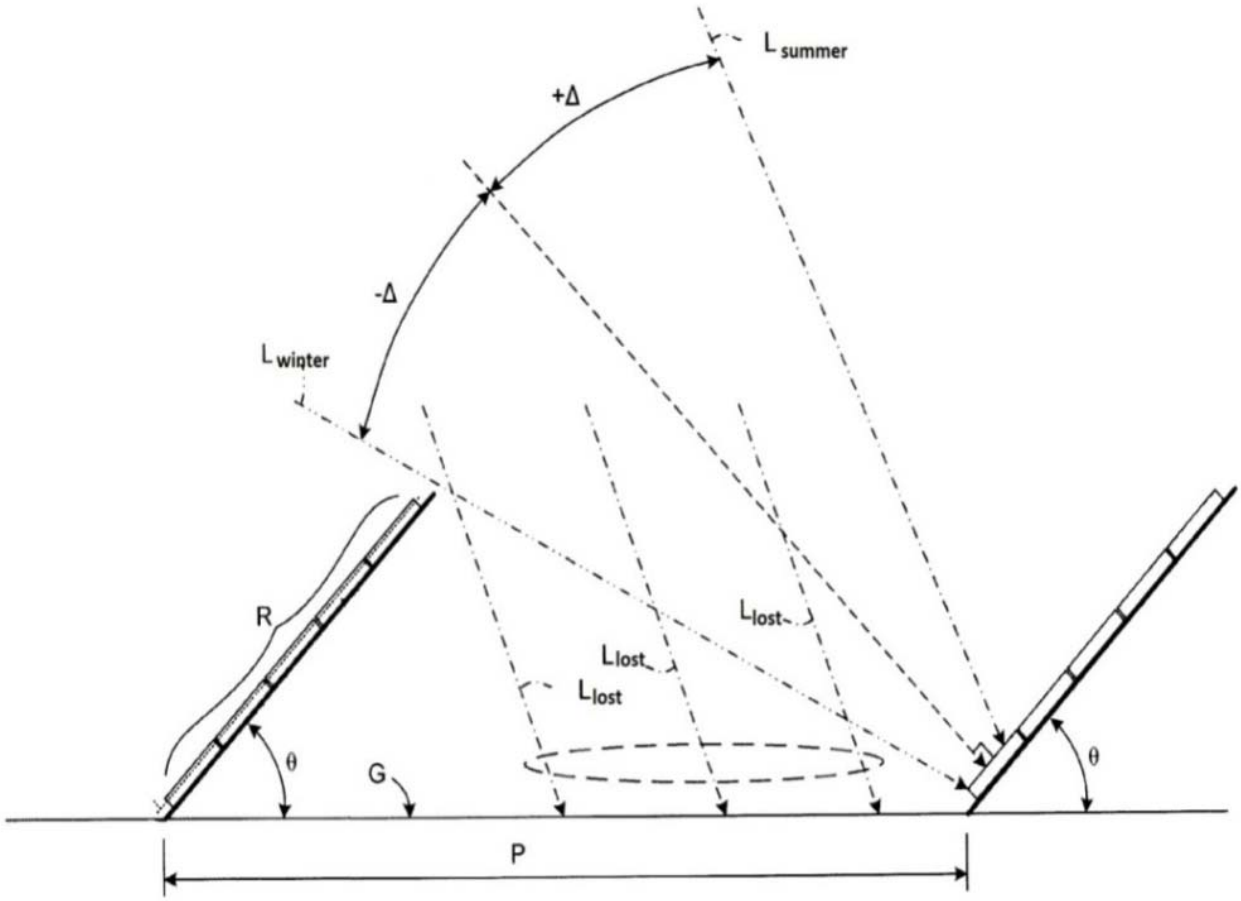

Figure 1 – A model of a photoelectric solar system (PhES system) installed on the earth's surface

A typical model of a photoelectric solar system (PhES system) installed on the earth's surface is illustrates in figure 1.

Figure 1 shows a top view of a similar converter. Here:

R – the surface of the solar cell

G – the surface of the earth

T – the width of the unit

O – the optimal angle of inclination of the photoelectric surface

P – the optimal distance between individual photo panels

This paper presents a low-cost and effective method for improving the model of the photoelectric converter mentioned above. This method is based on the use of lost sunlight L_{lost} cdue to redirecting it by micro-optical surfaces.

The main feature of the redirecting surface S is that, regardless of the position of the sun, the light is reflected from the surface and always gets the photocell R. Therefore, the system will be working the whole year. So, there is no need to use expensive structures that turn the system towards the sun. Its only drawback is the instability to the strong wind due to its volumetric location. In view of this drawback, alternative design models may be proposed.

The principle of operation of the redirecting surfaces is based on the laws of elementary geometric optics when light passes through different media. Depending on the method of action, this paper presents two different models of surface design [10, 11].

Model 1:

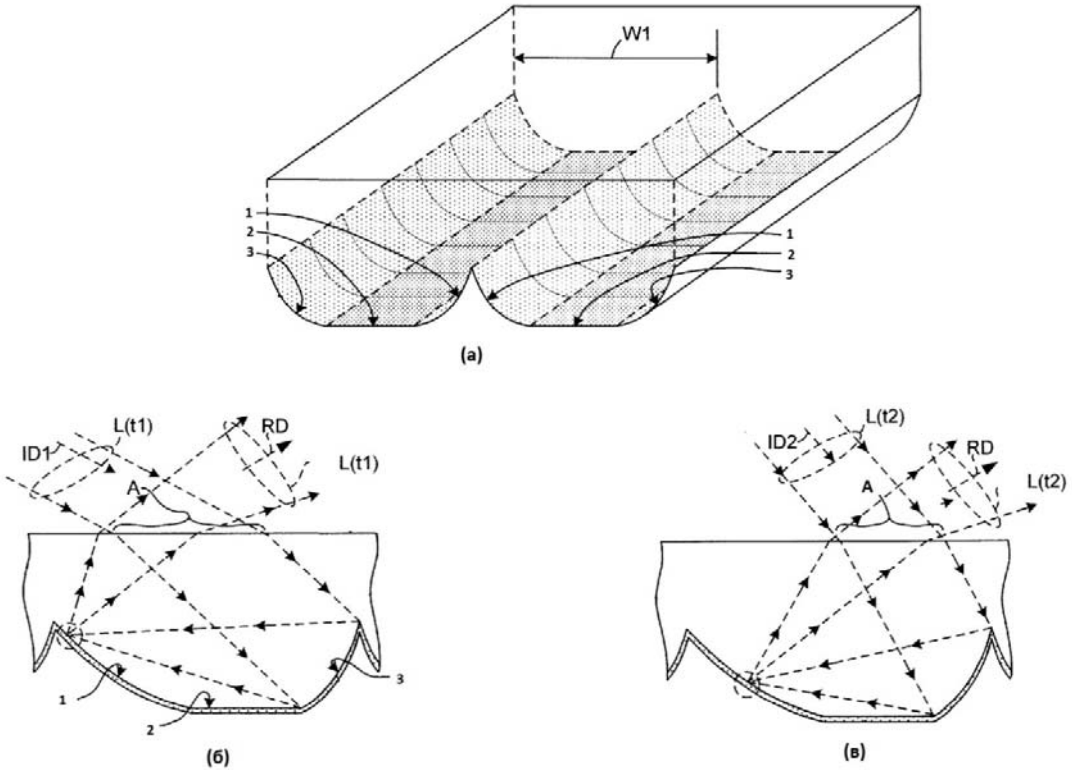

Figure 2 – Surface models: а – Three-dimensional pattern; б – rays are directed at a relatively small angle to the surface of the earth; в – redirecting element in the case of the corresponding time t2

Figure 2 shows a diagram of the first surface model in its three-dimensional design, moreover, the figure shows a several times enlarged element of the structure, where the numbers 1, 2 and 3 indicate the surface of the reflection of light when it passes through the inner part of the redirecting panel. The width of one "tooth part" of the structure is indicated by W1 and can take values from 0.05 mm to 50 mm. When the size of W1 is decreasing, the distribution of the reflected light on the surface of the solar cell is becoming more uniform. However, the production of small-toothed models will be more expensive than large-toothed ones.

The main advantage of the design presented in the model 1 is the presence of a smooth surface on the top layer of the panel, which greatly simplifies the solution of problems arising in the process of cleaning the structure.

Regions 1, 2 and 3 are mirror surfaces, where 1 and 3 have a parabolic shape, such that the light L after its reflection from the surface 3 is directed to the surface 1 and changes its direction so that when it exits the panel medium, it moves along the RD line.

Figure 2 (б) (lower left corner) shows the process of lightpassing through the panel at time t1, when the radiation is directed at a relatively small angle to the earth's surface. The letter A indicates the region of solar radiation, when the sun rays will be redirected to the photoelectric surface. The process of light passing can be described in the following way: the rays of the sun L(t1) are moving along the direction ID1 at the corresponding time t1, after passing through the upper surface, it will be directed to the mirror region 3. After the reflection, the light will be redirected to the surface 1, from which it will again rush to the upper edge of the panel. At refraction through this edge, the radiation will move along the RD line, which corresponds to the direction leading to the photoelectric cell.

Due to the basic property of the redirector in the case of the corresponding time t2 shown in figure 3(в), the light is initially directed along the ID2 line, after passing through the surface, it will also be redirected along the RD line, similar to the previous case described in figure 2(б). This property allows the system to function throughout the year, regardless of the position of the sun that greatly increases the efficiency of the design.

Model 2:

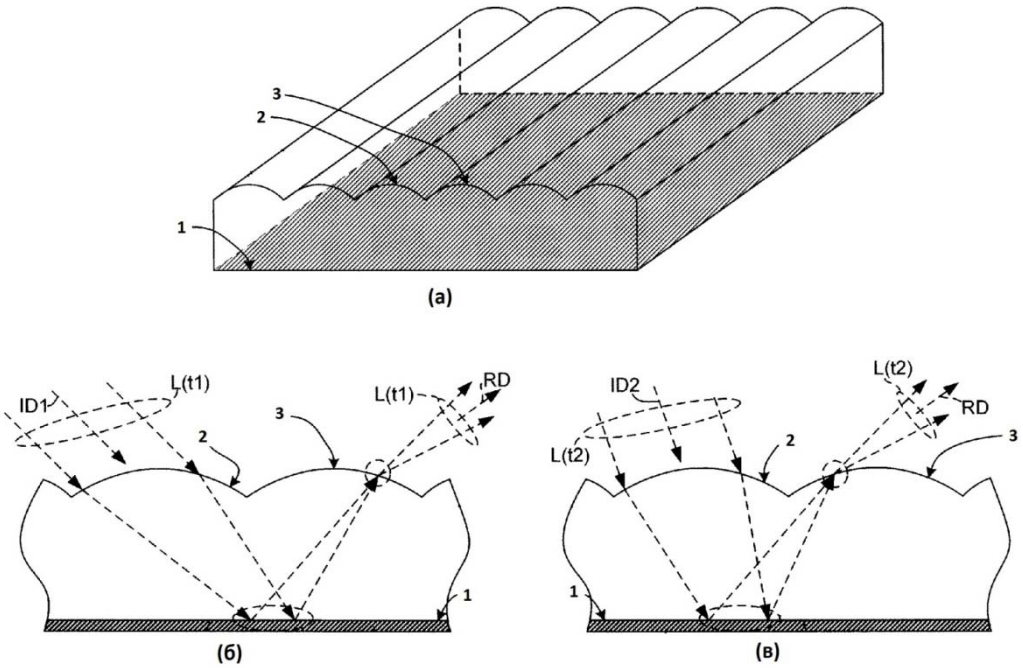

Figure 3 – Design model of the redirecting surface:
а – Three-dimensional pattern of the element; б – movement in the direction of ID1; в – the initial direction of ID2

Figure 3 shows the second possible design model for the redirecting surface. This model has a parabolic and rounded top surface. The bottom surface is like a smooth mirror. Three-dimensional pattern of the construction is presented in figure 3 (a). Here, the number 1 is the lower mirror layer of the system. And figures 2 and 3 show alternating parabolic circles.

The process of operation of this model is similar to the previous one: the sunlight L(t1) corresponding to the time t1 moves in the direction ID1,which has a relatively small angle of inclination to the horizontal plane (see figure 3(б)). After refraction through the surface 2 the rays move to the mirror layer 1. Reflected from this layer, the light is redirected to the parabolic region 3, refracted through it the light will have the direction RD and the ray moves directly to the photoelectric surface. For the moment t2, the ray will have an initial direction ID2, which is steeper relative to the horizontal plane than at the moment t1 (see figure 3 (в)). However, after passing through the redirector, the radiation will be directed along the RD line, the same direction as for the time t1. Thus, regardless the position of the sun, the structure will redirect the light to the surface of the photoelectric cell throughout the year.

A clear advantage of model 2 over model 1 is that it redirects almost all of the light falling on its surface, while model 1 uses the amount of light passing through the limited region- A. However, a significant drawback of the 2nd model is in convenience during the process of cleaning the upper surface, because it does not have as smooth shape as the 1stmodel.

Conclusion. So, in conclusion, it would be reasonable to consider all the advantages of the proposed system in this work. Firstly, as mentioned earlier, the design will operate 70% of time in a year, which in turn will increase the generation of photoelectric power by 25-30%. For example, let's assume that the system is installed on the world's largest photoelectric converter (AquaCalienteSolarProject),its power is 400 MW. If this capacity is increased by 30%, the amount of additional generated energy will be about 120MW, which is enough to provide electricity to the city with a population of 150-200 thousand people. In addition, it is possible to consider the reduction of electricity prices as a result of the installation of redirecting systems. Today, 1kW*hour of photoelectric energy costs about $ 0.15. Using the additional systems presented in this work, the price for 1 kW*h of energy of photoelectric converter will fall to about 0.1 dollars.

Secondly, as described earlier, the redirecting surfaces used in this project contribute to the uniform distribution of the reflected light on the surface of the solar cell compared to the concentrating parabolic systems presented above, which will help to avoid overheating of the system, and will cause long-term service of the structure.

Also, one of the most important features of this work is that the production of redirecting surfaces will be simple and inexpensive. In addition, it is important to note the fact that Kazakhstan and many regions of Central Asia are located at the latitudes advantageous for the installation of PhEC structures with additional systems proposed in this work. In view of this, it is possible to propose this project as a possible option for the development of alternative energy in the countries of Central Asia.

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КҮН ЭНЕРГИЯСЫН ПАЙДАЛАНУ ТЕХНОЛОГИЯСЫ ЖӘНЕ ПЕРСПЕКТИВАЛАРЫ

Аннотация. Бұл мақалада күн энергиясын пайдалану, күн энергиясын электр энергиясына айналдырудың әртүрлі тәсілдерін салыстырмалы талдау қарастырылған. Күн энергиясы – күннің терең қойнауындағы реакциялардың нәтижесінде пайда болған радиацияның кинетикалық энергиясы (негізінен жарық шығарудың), оның қорлары дерлік сарқылмайды. Табиғи экожүйелерде күн энергиясының кішкене бөлігі ғана органикалық заттардың потенциалды энергиясы ретінде ұсталып, сақталады. Олардың жіктелуіне байланысты экожүйелердің барлық басқа компоненттерінің энергия қажеттіліктері қанағаттандырылады. Күн энергиясын қолданамыз ба, жоқ па екеніне тәуелсіз, ол Жердің энергетикалық балансына және биосфераның күйіне әсер етпейді. Бұл жұмыстың басты жаңалығы – күн электр станциясы бұрын пайдаланбаған қайта бағыттаушы беттерін енгізу. Бұл конструкциялар фотоэлементтің бетіне біркелкі үлестіріп, жүйенің қызып кетуіне жол бермейді. Олар сондай-ақ оның тиімділігін айтарлықтай арттыруға ықпал етеді. Бұл жоба тұрғын үй-жайларды жоғары сапалы жарықтандыру үшін күн сәулесін қайта бағыттауға қабілетті. Бұл технологияның идеясы біркелкі емес беттерді микро-оптика жетістіктеріне қолдануға негізделген. Терезеден өткен жарық бағытын өзгертіп, төбені жарықтандырады, бұл өз кезегінде адамның көзіне түсетін тікелей сәулелердің пайда болуына жол бермейді.

Түйін сөздер: күн коллекторы, гелиосистема, жылу алмастырғыш, энергия көзі.

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ТЕХНОЛОГИЯ И ПЕРСПЕКТИВЫ ИСПОЛЬЗОВАНИЯ СОЛНЕЧНОЙ ЭНЕРГИИ

Аннотация. В данной статье рассмотрены вопросы использования солнечной энергии, проведен сравнительный анализ различных способов преобразования солнечной энергии в электрическую. Солнечная энергия – кинетическая энергия излучения (в основном света), образующаяся в результате реакций в недрах Солнца, ее запасы практически неистощимы. В естественных экосистемах лишь небольшая часть солнечной энергии улавливается и запасается в виде потенциальной энергии органических веществ. За счет их разложения удовлетворяются энергетические потребности всех остальных компонентов экосистем. Независимо от того, будем мы использовать солнечную энергию или нет, на энергетическом балансе Земли и состоянии биосферы это никак не отразится. Основной новизной данной работы является внедрение перенаправляющих поверхностей, ранее не использованных солнечной энергоиндустрией. Эти конструкции позволяют

равномерно распределить свет по поверхности фотоэлемента и не приводят к перегреванию системы. Также они способствуют значительному увеличению ее эффективности. Вдохновением для данного проекта послужила внедренная недавно в производство технология окон, способных перенаправлять солнечный свет для качественного освещения жилого помещения. В основе идеи данной технологии лежат достижения микрооптики с использованием неравномерных поверхностей. Свет, прошедший через окно, меняет свое направление и освещает потолок, что в свою очередь способствует избеганию прямого попадания лучей в глаза человека.

Ключевые слова: солнечный коллектор, гелиосистема,теплообменщик, источник энергии.

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REFERENCES

[1] Andreev S.V. Solar power plants. M.: Nauka, 2002.

[2] Vanke V.A., Leskov L.V., Lukyanov A.V. Space power systems. M.: Mechanical Engineering, 1997.

[3] Kharchenko N.V. Individual solar installations. M.: Energoatomizdat, 1991.

[4] Isembergenov N., Taissariyeva K., Seidalieva U., Danilchenko V. Microprocessor control system for solar power station // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technology sciences. 2019. 1(433): 107-111. https://doi.org/10.32014/2019.2518-170X.13

[5] Samigulina G.A., Nyusupov A.T., Shayakhmetova A.S. Analytical review of software for multi-agent systems and their applications // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technology sciences. 2018. 3(429): 173-181.

[6] IEA International Energy Agency, “Daylight in Buildings, A Source Book on Daylighting and Systems and Components,” A Report of IEA SHC Task 21 (2000).

[7] Walze G., Nitz P., Eul J., Georg A., Gombert A., Bläsi B., Hoßfeld W. Combination of Microstructures and Optically Functional Coatings for Solar Control Glazing // Solar Energy Materials and Solar Cells. 2005. Vol. 89. 2-3. P. 233-248.

[8] Partain, Larry D, ed. Solar Cells and Their Applications. New York: John Wiley & Sons, 1995.

[9] Klammt, A. Neyer, Helmut F.O. Müller. Microoptics for Efficient Redirection of Sunlight. Germany: TU Dortmund University, 2010.

[10] W.J. M. van Bommel, G.J. van den Beld. Lighting for work: a review of visual and biological effects // Lighting Res. Technol. 2004. 36,4. P. 255-269.

[11] Zweibel Ken. Harnessing Solar Power: The Photovoltaic’s Challenge. New York: Plenum Press, 1990.

[12] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[13] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[14] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[15] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[16] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[17] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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DEVELOPMENT OF A VALVE GENERATOR WITH A VARIABLE FREQUENCY OF ROTATION

Abstract. The article deals with the maintenance of the required value of the output voltage on an electric generator driven by a variable speed shaft. Schemes for creating such a synchronous generator with the possibility of combining the winding armature connections depending on the frequency of rotation of the rotor shaft are proposed. A test sample was tested without a gear generator, and experimental data were presented.

Key words: electric generator, rotational speed, anchor winding, valve switch, rectifier, inverter.

Introduction. Interruptions in power supply of agricultural production cause significant material damage and disorganise the process. To prevent such consequences on the farming objects of Kazakhstan is quite a difficult task since they do not have network redundancy and are far from large settlements and each other. At the same time, a significant part of agricultural products of Kazakhstan (about 90%) is produced in numerous (more than 250 thousand) peasant, farmer and cooperative farms of relatively small and medium size [1]. At such facilities, the use of traditional (petrol and diesel) or non-traditional (solar, wind, etc.) sources of electricity is uneconomical. In the literary sources [2] for the backup power supply of low-power agricultural facilities tractor driven power generator sets (PGST) are recommended.

It should be noted that the existing PGST is designed to operate from a power shaft (PS) with a specific rotational speed (mostly 1000 rpm) and have different rotational speed conversion mechanisms (gear reducers, massive pulleys, etc.) since they have synchronous generators with speeds of 1500 and 3000 rpm. The used rotational speed conversion mechanisms increase the weight of the PGST, reduce the reliability of the design and require additional maintenance [1, 2].

One of the essential differences between renewable energy is the lack of predictability and lack of control by the consumer. Ensuring reliable power supply can be achieved using a combination of traditional hydrocarbon fuels and renewable energy sources. As a reliable source based on hydrocarbon fuels, a diesel generator has found the full application. Recently, gas-piston and gas-turbine installations have become popular. The advantage of diesel power plants (DPP) is their versatility, low cost and fast payback period. The versatility of internal combustion engines is the ability to use a power shaft for rotating an electric generator and to provide a mobile autonomous power supply system.

The economic efficiency of diesel power plants, including gasoline, is determined by the specific consumption, which is equal to the ratio of energy production to fuel consumption for an hour. Particular use depends on the operating conditions: temperature of the environment, load, speed.

The majority of DPP includes a frequency rotation regulator, output voltage values. This configuration allows connecting a load of AC directly to the generator. As synchronous generator machines and, more rarely, asynchronous tools are more often used. To maintain the frequency constant of the current, the drive motor must rotate at a constant speed, regardless of the load. Maintaining the nominal rate at low pressure increases the specific fuel consumption and reduces the working life, which is reflected in the cost of generated electricity. Resource reduction is associated with *cylinder coking*. It occurs when the

load is reduced to less than 20% of the rated, and the rated speed is maintained. In the conditions of remoteness and lack of centralised power supply, the relevance of issues of reducing the cost of electricity and increasing equipment life is very high [3]. In the articles [4, 5], the authors present the results of an experimental study of the efficiency of using variable speeds of diesel generators by the load change. A comprehensive analysis of many operational indicators was carried out: emissions, consumption, power quality. From the study of the results of experiments, it follows that a change in rotational speed with a change in load can *reduce fuel consumption* by 20%. The dependence of the reduction in specific consumption with decreasing pressure with a corresponding decrease in rotational speed is almost straightforward. When reducing the load to 40% of the nominal value, the maximum rate should be reduced to an amount of 50% of the nominal value.

Further reduction of the rotational speed leads to unstable operation of the diesel engine, into the flesh to a complete stop. When loading below 40%, specific consumption is growing. The articles [6, 8, 9] provide an analysis of the effect of loading inverter diesel generators on their specific fuel consumption. The experiments were carried out using diesel power plants of various capacities 10 kW (KDE12 EA3) and 200 kW (8ЧН13 / 14 (ЯМЗ 33-238Н)). The results of the tests showed similar speed optimal modes. In the figure 1, the optimal speeds of diesel power plants are given in the electrical load changes. For ease of analysis, the characteristics are constructed in relative units.

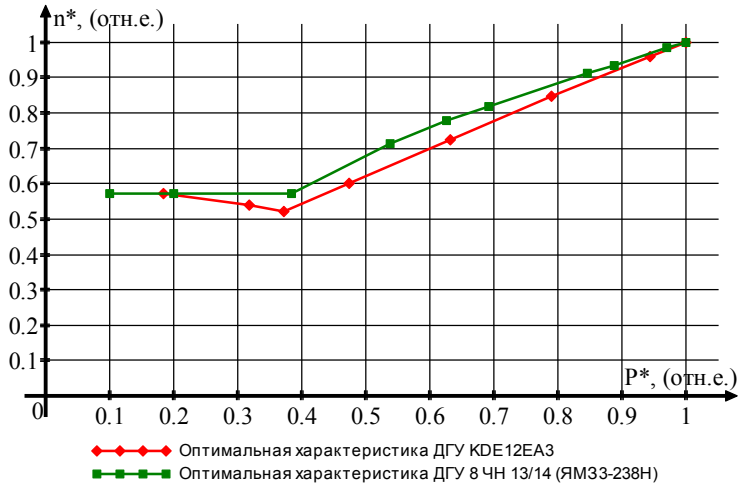

Figure 1 – The optimal speed mode with variable DPP load

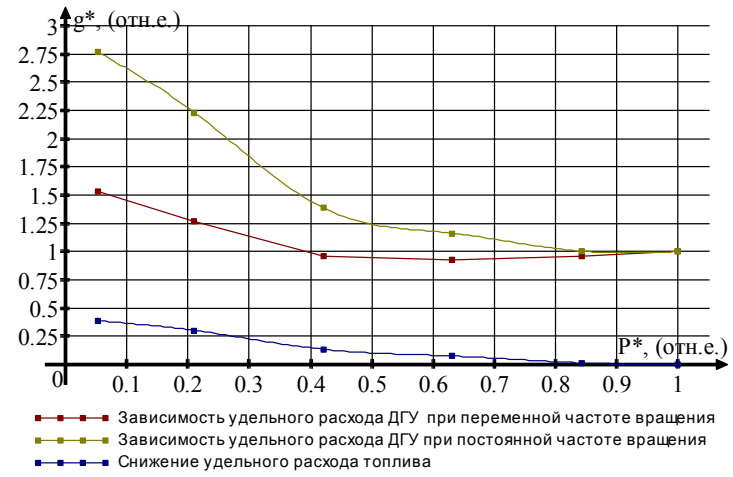

Figure 2 – The specific flow diagram is when the rotational speed is coordinated
with the rotational speed and while maintaining a constant rotational speed of DPP KDE12 EA3

When working on a free load, the typical load change schedule is variable, and there is a probability of pressure occurring less than 15% [5].

The decrease in the specific consumption from the rotational speed matching with the KDE12 EA3 engine load is shown in figure 2. It can be seen from the figure that for autonomous consumers, fuel savings at low pressures can bring savings of up to 30%.

This mode of operation of the drive motor imposes its requirements on an electromechanical converter, which may consist of an electric generator or an electric generator with voltage converters (rectifiers, inverters). It is necessary to analyse the consistency of the characteristics of the engine with the features of the generator. The main requirement for coordinated operation of a generator with a drive engine is to maintain the voltage value and satisfactory efficiency at a variable frequency of rotation and power.

Formulation of the problem. When used as a drive motor, the power take-off shaft of agricultural machinery poses the problem of matching the speed modes of the generator and the power take-off shaft: obtaining the required voltage from the drives at different speeds or obtaining the energy of varying magnitude from one trip. At variable or different rates, the question arises of ensuring the constancy of the frequency of the alternating current and ensuring the required voltage value. There are two leading solutions: the use of synchronised asynchronous generators and the use of valve-type asynchronous and synchronous generators. According to the authors, one of the promising solutions is a variant using a valve-type synchronous generator and an autonomous inverter, which converts direct current from the rectifier into alternating current with a constant frequency. Such installations are recently called inverter diesel generators [6].

Synchronised asynchronous generators is an asynchronous machine with a phase rotor [3-5]. The study of operating modes of devices of this type in diesel plants with variable rotational speeds is considered in the works [10]. The stator winding is connected to the mains or the consumer directly, and the phase winding of the rotor is connected to the frequency converter. The frequency of the stator winding depends on the slip s; therefore, the condition of maintaining a constant rate f_2 is made by smoothly adjusting the frequency of the current in the rotor f_1. Therefore, when a frequency converter changes the rotor speed, the frequency of the current in the rotor is inversely proportional by reducing the rate of rotation of the frequency of the current in the rotor increases. The supply of the rotor winding with a voltage of increased frequency leads to an increase in losses in steel and the rotor winding. Losses will increase in modes other than the calculated ones, which means an increase in losses at rotational frequencies lower than the calculated ones, which reduces ECE at low revs. This was reflected in the limited range of changes in power in the article [5, 6]. The works provide data on the shift in generator ECE with power changes. For a machine with a rated power of 150 kW, the deviation of the ECE value of 2-5% is maintained at a lower power value of 50 kW. The article [4, 5] discusses the use of machines in the range of variation of the rotational speed of 950-1050 rpm.

In autonomous power plants, synchronous generators with claw-shaped poles, inductor generators and, less commonly, asynchronous generators, are widely used. The main criterion in favour of the listed generators is the mechanical reliability of the structure (the ability to operate at high speeds), low weight and dimensions[11], and a soft external characteristic improves the consistency of the generator characteristics with batteries, by limiting the load current.

According to the results of the research [6], it was shown that traditional generators without additional devices could not ensure the maintenance of the voltage value. By reducing the speed below 53-55% ensure the preservation of voltage due to saturation of the magnetic circuit of the generator. The more extensive the frequency change range, the lower the generator ECE. The use of inverters with maintaining a constant voltage value with a change in the input voltage can extend the working field. However, the question of maintaining the ECE of the generator does not provide such a solution.

Thus, the development of a universal generator rotating from a power shaft with different and variable rotational speeds and at the same time maintaining the required voltage and satisfactory ECE without using specialised devices is relevant.

A group of scientists of the Almaty University of Power Engineering and Telecommunications has developed an electromechanical converter with a wide range of rotational frequency and power, capable of maintaining a constant voltage value with a cubic dependence of energy on the rotational frequency. The electromechanical converter operates at a reduction of the nominal (calculated) speed of more than five

times, and power, respectively, more than 125 times and at the same time maintains a satisfactory value of ECE in the range from 0.75 to 0.94 [12]. The idea of development is to manufacture the anchor winding of the generator from several parallel branches connected to their rectifier and forming valve blocks. The valve blocks are combined into a switched rectifier with the possibility of changing in series, in parallel and series in parallel. In fact, in one case several generators are connected for different operating modes. The switched rectifier is a discrete regulator and the smooth maintenance of the voltage produced by the excitation current. A switched rectifier dynamically changes the stages under load. Implementing a dynamic switching without a switched rectifier will be difficult. Therefore, when working as part of a wind power plant, a large number of parallel branches with a minimum number of switching contactors is justified by the scheme.

When working as part of DPP the range of rotational speed variation is 1: 2, the rotational speeds of the power take-off shaft may differ by three times for different agricultural equipment. Figure 3 shows a schematic solution for a universal generator for free use, but by switching the armature winding circuit in it is made without load.

Therefore, it is proposed to adapt the idea of an electromechanical converter with a switched rectifier [12] to agricultural installations and technology. Universal valve generator should operate at different speeds of 1: 3 and power (in the range of 1: 4 or more).

The valve generator presented on figure 3, which has an anchor winding consisting of "n" parallel branches (in the particular case n = 2) and "n" switching devices, and one single-phase rectifier. The beginning of the first parallel branch is connected and forms a star connection. The ends and the beginning of the other parallel branches through the switching devices are connected and with the rectifier through switching devices. The ends of one of the parallel branches are connected to the rectifier.

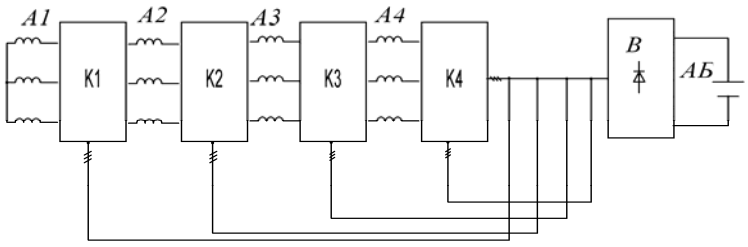

Figure 3 – Valve generator

A change in the connection scheme of parallel branches is made on the AC side, which imposes additional requirements on switching equipment. The development of semiconductor switches of alternating current makes it possible to abandon the switching of valve blocks with each other on direct current.

At a high frequency of rotation, the switching devices connect all the parallel branches according to the "star" scheme and parallel to each other, each of which is connected to a rectifier. When operating at a lower frequency of rotation, the switching devices connect lateral branches in series with each other. The number of switches depends on the number of parallel branches.

A circuit solution is proposed for a universal valve generator rotating from a power take-off shaft with the various and variable rotational speed with the maintenance of the required voltage value and satisfactory ECE.

From the previously developed circuit solutions of an electromechanical converter with a switched rectifier, this circuit solution is distinguished by the possibility of using a standard rectifier and the option of turning on the AC side.

Theory. According to the theory of electric cars, the output voltage of the generator can be determined by the expression [13]:

$$U_{\Gamma} = 4{,}44 \cdot f \cdot W_{\phi 1} \cdot \Phi = 4{,}44 \frac{p \cdot n}{60} W_{\phi 1} \cdot \alpha \cdot \tau \cdot l \cdot B_{\delta} = 4{,}44 \frac{p \cdot \tau \cdot l \cdot \alpha}{60} W_{\phi 1} \cdot n \cdot B_{\delta} = K_{\Gamma} \cdot W_{\phi 1} \cdot n \cdot B_{\delta}, \quad (1)$$

where $W_{\phi 1}$ – the number of effective the number of effective turns in one parallel phase branch; B_δ – air-gap induction; K_Γ – constructive constant of generator; p - number of pole pairs; α – pole overlap coefficient; τ – pole division; l – length of the core; f - current of frequency; n – calculated frequency of rotation.

From the phrase it is seen that reducing the rotational speed twice will require a corresponding increase in induction (excitation current), which in turn will lead to a rise in losses in the excitation winding and saturation of the magnet wire. According to the recommendation for the design of electric machines, the induction in the air gap is taken in the range of 0.6-0.7 T, while the selection in the prongs usually reaches a value of 1.3-1.6 T, and the saturation of electrical steel in the field of 1.8-1, 9 T [14]. Consequently, there is no possibility of increasing the induction in the air gap in proportion to the change in rotational speed. Designing a machine with a low induction value will lead to oversized weight and size indicators and an increase in the influence of the armature response on the load characteristics. This follows from the expression defining the Arnold coefficient [13]:

$$\frac{D^2 l_1 n}{P^/} = \frac{6{,}1 \cdot 10^7}{(\alpha_i k_\phi k_o A B_\delta)} = C_A \ , \tag{2}$$

where C_A – Arnold machine constant; P – rated power; k_ϕ – curvy field form factor; k_o – winding coefficient; A – linear load.

As follows from expression (1) with low induction, there is need to increase the number of turns in the winding, and this, in turn, will affect the magnitude of the reaction of the armature, as follows from the expression [13]:

$$F_P = 0{,}9 \cdot m \frac{W_1 \cdot k_0}{p} \cdot I_\Phi , \tag{3}$$

where m – number of phases; I_ϕ – phase current.

For the proposed circuit design of the valve generator, the expression for determining the voltage varies as follows.

The voltage of the universal generator with two parallel branches, according to its concept, allows two stages of switching the connection circuit of the winding branches and are determined by the expressions:

- the first stage, at the highest rotation frequency, all the branches are parallel [12-14]:

$$U_\Gamma = U_1 + U_2 = K_\Gamma \cdot W_{\Phi 1} \cdot n \cdot B_\delta \tag{4}$$

- the second stage of the branch is connected in consistently;

$$U_\Gamma = U_1 + U_2 = 2W_{\Phi 1}(K_\Gamma \cdot n \cdot B_\delta) \ . \tag{5}$$

Expression (1) can be rewritten as follows:

$$U_\Gamma = U_1 + U_2 = a \cdot W_{\Phi 1} \cdot K_\Gamma \cdot n \cdot B_\delta \ . \tag{6}$$

Switching the connection pattern of parallel branches is equivalent to changing the number of turns in parallel branches of the armature winding. According to expression (1), as the windings increase in the winding, the induction required to maintain the voltage decreases.

Results of experiment. The efficiency of the concept was tested on an experimental setup, which is shown in figure 4.

The test bench is assembled at a laboratory based at the Almaty University of Power Engineering and Telecommunications. As the generator was used automotive type generator G-286V (SG). The main technical characteristics of the generator type G-286V, rated voltage 14 V, rated current 50 A, the rotational speed with voltage regulator during self-excitation and voltage 13V without load 650 rpm, with load current 20A at 750 rpm.

The maximum load current is 75A and at 5000 rpm. The generator is rotated by a driving motor (M) of a direct current P32M, with a power of 2.2 kW, with a nominal speed of 1500 rpm. The anchor winding of the generator is rewound and made with two parallel branches for a voltage of 24 V. The field winding has not changed.

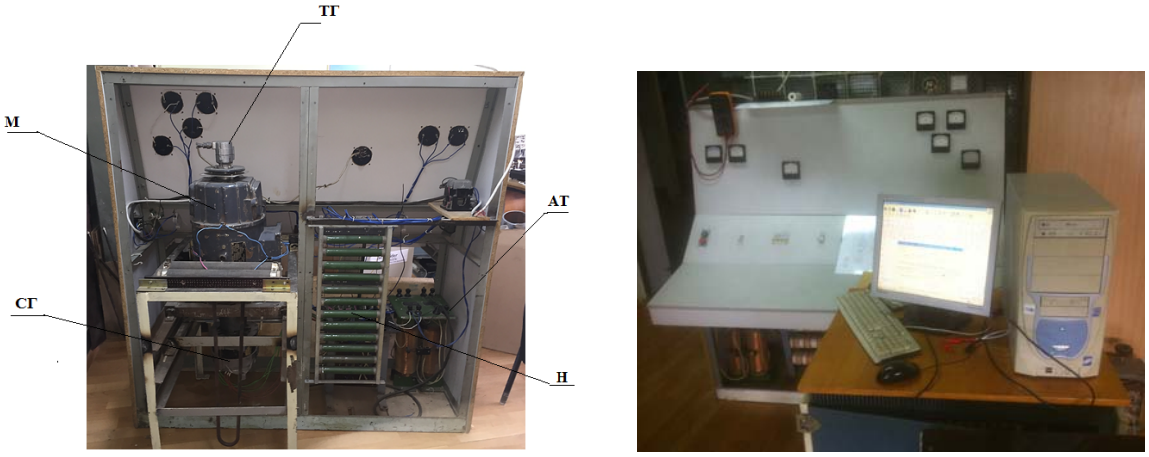

Figure 4 – Exterior view of the test bench

A schematic diagram of the test bench is shown in figure 5. The power shaft was modelled by a DC motor of independent excitation P-32M (M), with a power of 2.2 kW and a rotational speed of 1500 rpm. Regulation of the frequency of rotation of the generator was made by regulating the voltage of the engine through an autotransformer.

According to the concept, the synchronous generator SG is connected to the shaft by a drive motor M in which the angular velocity is measured with the TG tach generator TG. The windings of the SG are divided into two parallel branches A1 and A2, which are connected to the rectifier through the switching keys K1 and K2.

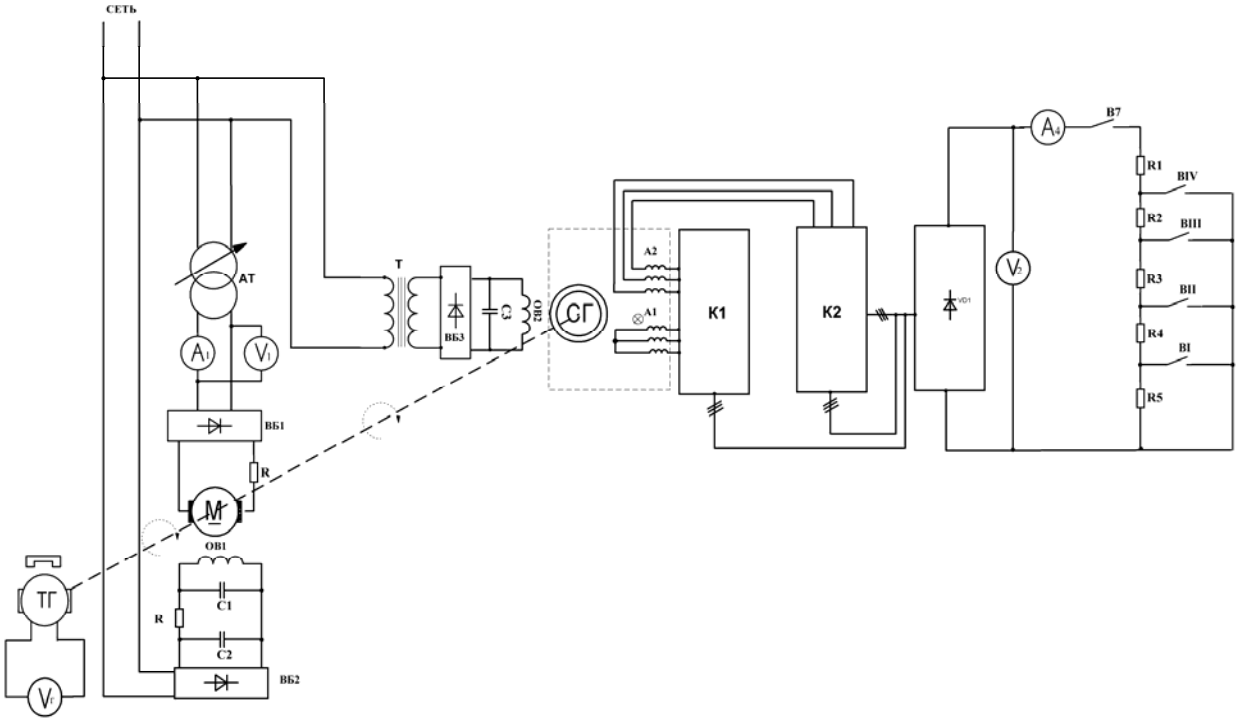

Figure 5 – Schematic diagram of the test bench

Voltage in parallel branches was measured on the DC side at the terminals of the rectifiers and the AC side at the terminals of the parallel branches.

Based on the experimental data in figure 6 shows a unique characteristic of idling.

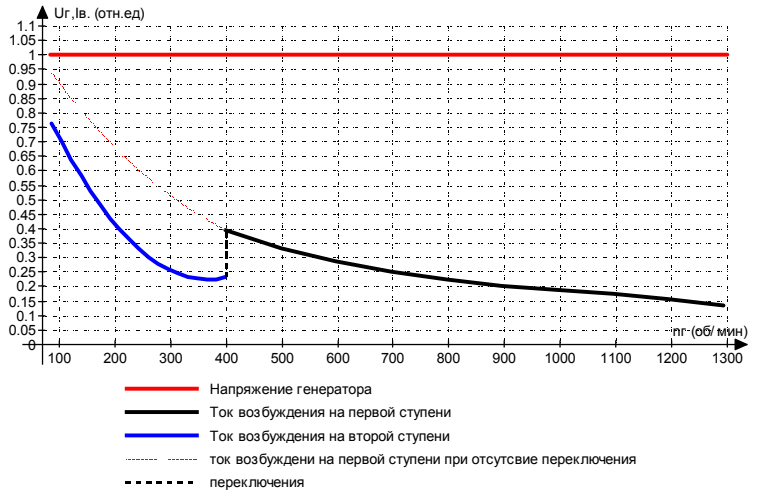

Figure 6 – The special characteristic of idling of the generator

It is built at a constant voltage (line 1) and when the rotational speed changes from 1250 to 100 rpm. To match the scale of the voltage and excitation current of the generator, they are built in relative values. The voltage throughout the entire range of changes in rotational speed is equal to the nominal value, and in relative units, it is taken as a unit. The excitation current at a rotational speed of 100 rpm is 3 A, and this maximum value is considered as a unit.

Switching parallel branches makes it possible to increase or decrease the voltage value following the needs. Figure 7 shows the experimental characteristics of idling.

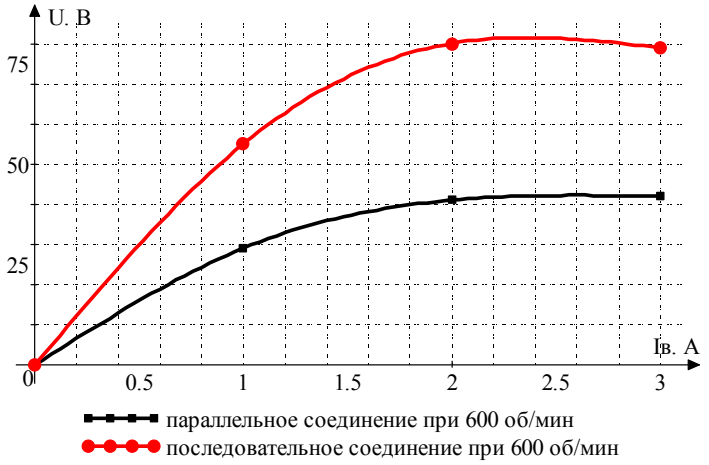

Figure 7 – Special idle characteristic

Discussion of the results. The experiment used an automotive generator G286V, which was rewound at a design speed of 1200 rpm. The number of parallel branches taken a = 2, power 300 watts. According to the concept of a valve generator, with "a = 2" the number of stages is 2. In figure 6 voltage line (line 1) excitation current in two steps (curves 2, 3) are given. The dotted line shows the change in the excitation current in the absence of switching. According to the experimental results it can be seen that the generator voltage is kept constant throughout the entire range of rotational speed.

Recalculation of the generator was carried out on the calculated rotational speed of 1200 rpm. and with a lower calculated induction in the air gap of 0.2 Tesla. The range of variation of the excitation current is from 0.4 to 3 A. On the graph, the maximum value of the excitation current is 3A. The curve of the excitation current in the first stage in the absence of switching in relative units varies in the range from

0.15 to 0.9. The wide range is due to the low value of the calculated induction. Turning to the next stage reduces, according to the concept, the amount of the excitation current by two times (dotted curve line connecting curve 2 and 3). Characteristic of idling VG is determined by the dependence of the excitation current $I_в$ on the rotation frequency $n_г$, with a constant output voltage U_I=const and $I_н$=0. It can be seen from the figure that when idling at lower speeds to avoid steel saturation by switching the connection circuit of parallel branches, the excitation current can be reduced with constant maintenance of the output voltage.

In figure 7 when switching the circuit for connecting the parallel branches, it can be seen that, with two parallel branches, switching from a parallel connection to a serial one increases the voltage twice. At the same time, the rotational speed remains constant. The range of voltage variation while maintaining the rotational speed is directly proportional to the number of parallel branches. The generator power depends on the frequency of the calculated rotational speed and is determined by the expression (2).

Findings and conclusion. The article speaks on the efficiency of the proposed concept of a valve generator for an autonomous power plant intended for remote agricultural consumers, designed to generate voltages of various sizes at constant speeds or to maintain a constant value of energy at different rates [15].

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ЖИІЛІГІ ӨЗГЕРІСТІ БІЛІГІ БАР ЖЕТЕГІНДЕГІ ВЕНТИЛДІ ЭЛЕКТРОГЕНЕРАТОРДЫ ЖАСАУ

Аннотация. Мақалада жиілігі өзгерісті білігі бар жетегіндегі вентилді электрогенератордағы шығыс кернеуі деңгейін қажетті мәнде тұрақтандыру сұрақтары қарастырылды. Ротор білігінің айналу жиілігінен якор орамдарының әмбебап қосылу мүмкіндігі бар синхронды генератор сұлбасы ұсынылды. Редукторсыз жалғанған электргенератордың тәжірбиелік үлгісі сынақтан өткізіліп эксперименттік мәліметтер келтірілген.

Түйін сөздер: электрлік генератор, айналу жиілігі, якорлық орам, вентильді коммутатор, түзеткіш, инвертор.

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РАЗРАБОТКА ВЕНТИЛЬНОГО ЭЛЕКТРОГЕНЕРАТОРА С ПРИВОДОМ ОТ ВАЛА ПЕРЕМЕННОЙ ЧАСТОТЫ ВРАЩЕНИЯ

Аннотация. В статье рассматриваются вопросы поддержания требуемого значения выходного напряжения на электрогенераторе с приводом от вала с переменной частотой вращения. Предложены схемы создания такого синхронного генератора с возможностью комбинирования соединений обмоток якоря в зависимости от частоты вращения вала ротора. Проведено тестирование опытного образца безредукторного электрогенератора и представлены экспериментальные данные.

Ключевые слова: электрический генератор, частота вращения, якорная обмотка, вентильный коммутатор, выпрямитель, инвертор.

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REFERENCES

[1] Umbetkulov E.K. The use of electric generators driven by tractors for back-up power supply of dairy farms // Materials of Int. scientific and practical conf. Almaty: KazNAU, April 17-18, 2008. P. 267-270.

[2] Budzko I.A., Zul N.M. Power supply of agriculture. M.: Agropromizdat, 1990. 446 p.

[3] Gerasimov A., Tolmachev V., Utkin K. Diesel power stations. The work at a variable frequency of rotation of the diesel // Electrical Engineering News. St. Petersburg, 2017. 1(103) (in Rus.).

[4] Obukhov S.G., Plotnikov I.A. Experimental study of a diesel generator set at a variable frequency of rotation // Bulletin of the Tomsk Polytechnic University. Resource of Engineering. 2015. Vol. 326, N 6. P. 95-102 (in Rus.).

[5] Zavalishin V.V. Fuel economy in the generation of electricity by a diesel generator set with a variable frequency of rotation of the diesel // SSTU Bulletin. 2010. N 3(46). P. 128-136 (in Rus.).

[6] Lukutin B.V., Shandarova E.B. Modes of operation of a synchronous generator of an inverter diesel power station. Tomsk: National Research Tomsk Polytechnic University (in Rus.).

[7] Lukutin B.V., Klimova G.N., Obukhov S.G., Shutov E.A., Parnikov N.M. Formation of energy-efficient modes of an inverter-type diesel power station. Bulletin of HEI // Electromechanics. 2009. N 6. P. 80-82 (in Rus.).

[8] Grigoriev A.V., Kolesnichenko V.Yu. Improving the efficiency of operation of ship diesel power plants // Bulletin of the State University of Marine and River Fleet Admiral Fr. Makarova. Vol. 6. P. 39-43 (in Rus.).

[9] Duraev N.N., Obukhov S.G., Plotnikov I.A. Simulation model of a diesel engine to study its performance at variable speeds (in Rus.).

[10] Tajuddin Waris. Variable Speed Constant Frequency Diesel Power Conversion System Using Doubly Fed Induction Generator (DFIG) PESC Record - IEEE Annual Power Electronics Specialists Conference July 2008. P. 2728-2734.

[11] Obukhov S.G., Sipailov N.Yu., Plotnikov I.A., Sipailov A.G. Characteristics of a synchronous generator operating as part of an invertor diesel power station // Bulletin of higher educational institutions. Electromechanics. 2012. N 5. P. 41-45 (in Rus.).

[12] Bakenov K.A. Electromechanical converter for a wind power plant. Thesis. Almaty, 2010 (in Rus.).

[13] Kopylov I.P. Designing of electric cars. M .: Energy, 1980. 488 p. (in Rus.).

[14] Balagurov V.A. Design of special electric machines of alternating current. M.: Higher school, 1982. 272 p. (in Rus.).

[15] Kasymbekov Zh.K., Atamanova O.V., Kasymbekov G.Zh. (2018) Hydro-electrostation of hydrocyclone type of small power for local energy supply // Bulletin of National academy of sciences of the Republic of Kazakhstan. 2018. Vol. 5, N 375. P. 48-54. https://doi.org/10.32014/2018.2518-1467.6 ISSN 2518-1467 (Online), ISSN 1991-3494 (Print).

[16] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[17] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[18] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[19] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[20] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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NANOENERGETIC MATERIALS AND LOW-CARBON NANOENERGETICS: REGULARITIES, TECHNOLOGY AND RAW PRODUCTS

Abstract. Physical, physicochemical, and chemical laws have been discovered and studied, and the technology of energy efficient production from substances (carbon, metal oxides, salts and minerals) that make up low-grade coal rocks has been substantiated:

– nanoenergetic materials (nanocarbon, nanopowders of silicon, aluminum, titanium, iron, manganese, magnesium, etc.);

– low-carbon liquid fuel which is environmentally friendly, of high-calorific quality comparable to natural gas, but safe, is much cheaper in price and convenient for transportation and storage in comparison with gas. It has been established that the sizes of nanoparticles of abrasion, microcracks and nanopores of rocks are critical technological parameters of the energy efficient production of nanoenergetic materials and the development of low-carbon nanoenergetics.

Key words: low grade coal rock, ash content, cracks and micropores of micron-nanodimensions, physical field, vacuum, discharge shock waves, hydroconversion, dry conversion, strength of internal and external electric and magnetic fields.

Introduction. Addressing to the American Physical Society in December 1959, Prof. Richard Feynman, the Nobel Prize winner in Physics, spoke about the possibility of creating "defect-free substances at the atomic-molecular level". The scientific community considers him as the founder of science about nanosubstances studying development and interaction regularities of nanoparticles, their agglomerates and structures [1]. In 1974 the term "nanotechnology" was defined as "separation, consolidation and deformation of materials by one atom or by one molecule" by Norio Taniguchi, Tokyo Science University Professor, in his paper, "On the Basic Concept of Nanotechnology" [2, 3]. The current concept of nanotechnology lies in programmed manipulation of individual molecules and atoms, in controlled regulation of the structure and composition of various nanomaterials with sizes determining qualitative and other fundamental parameters, properties and areas of their use [4, 5]. Nanotechnology is divided into groups by production methods [1-5]:

– powder metallurgy (electro-discharge sintering; gas-phase deposition and compaction);
– plastic deformation (shock effects; equal-channel angular pressing);
– amorphization (crystallization from the amorphous state; sol-gel synthesis, peptide synthesis);
– film coating (chemical and physical deposition of coating from the gas phase);
– nanocarbon technology;
– machine (nanorobots; molecular assemblies; self-replicating nanomachines);
– bioengineering (complexes of nanoparticles and surface DNA molecules, nanoparticles, layers of liquid crystals and surface DNA molecules, living cells; transformation of ordinary cells into stem cells replicating to human organs).

USA, China and Japan occupy the leading positions in nanotechnology and nanoindustry starting their research in the 80s of the last century. They are the first countries to start national programs such as the Japan's "National Program of Work on Nanotechnology" in 1999, USA's "National Nanotechnology Initiative" in 2000 and China's "National Program of the Development of Nanotechnology for the period from 2001 to 2006" in 2001 (extended to 2030). With a slight delay, nanotechnological programs were also adopted by the European Union (2003) and the Russian Federation (2005). To date, more than 30 countries have adopted similar programs. In general, nanotechnology is becoming a cross-cutting way of the development of the world economy, defense, security and environmental well-being on the planet. The market of nano-goods, being a little more than 2.5 billion US dollars in 2000, exceeded 30 billion US dollars and achieved an annual increase of almost 15%. According to the forecast of the National Science Foundation of the USA, nanoelectronics will take the lead in sales in the coming years occupying at least 40% of the volume of global nanoindustry goods.

The rapid growth of the market of nanoindustry products is caused by significant improvements in their production technology, consumer qualities and properties, a decrease in the cost and price of nano-products due to the replication of similar products by additive 3D printing. In this regard, the availability of affordable raw materials and energy resources, energy-efficient technology and devices which implement it (equipment, apparatus, reactors, etc.) is of particular relevance for the production of nano-materials [1-5].

Considering the absence of the unambiguous term "nanomaterial" let us call a particle with linear dimensions varying from 1 nanometer (**nm**) to 30 nm as a **nanoparticle,** and also let us call a nanoparticle with an ordered arrangement of atoms and ions as a **nanocrystallite. Nanomaterials** are dispersed materials with structural elements (nanoparticles, nanocrystallites, their blocks and clusters) having nanosizes from 1 nm to 10 nm in one or two dimensions, qualitatively new physical (weight, strength, electrical conductivity, thermal conductivity, etc.), chemical (bond energy, degree of freedom, conditional valence, etc.), functional and operational properties and characteristics [4,5]. These definitions can be attributed to nanoenergetic materials; nanoparticles of carbon, silicon, electrically conductive metals, nanocarbon tubes, uncoated and coated with electrically conductive layers of photoelectric nanocrystallites in particular.

Raw products for nanoenergetic materials and low-carbon nanoenergetics. We consider low-grade (energetic) coal rocks with medium (up to 25% and less) and large (from 25% and above) ash content as the main raw material for the production of nano-energy materials. According to the "BP Statistical Review of World Energy" Kazakhstan has the reliably established coal reserve of 34.02 billion tons and is ranked as the ninth in the world. According to the statistics from the Energy Information Administration of the United States Kazakhstan is ranked as the ninth in terms of annual coal production (115 million tons per year). At the same time, only 10% of Kazakhstan's coal reserves are related to coking coal, and its annual production exceeds 30 million tons with 22 million tons being exported to the Russian Federation (the Ministry of Energy of the Republic of Kazakhstan statistics).

Thus, the bulk of coal in Kazakhstan belongs to high-ash energetic coal which needs to be revealed in its energy-chemical, metallogenic and mineral potentials. Let us consider the chemical composition of the ash (in % of mass) of energetic coals:

– medium ash (ash content of 20.5%) of the Shoptykol deposit, the Maykube mine – 45.53% SiO; 21.63% Al_2O_3; 14.75% Fe_2O_3; 5.25% CaO; 2.86% MgO; 1.72% Na_2O; 1.90% K_2O; 4.25% PbO_3; 0.91% TiO_2 0.78% P_2O_3; 0.50% SO;

– high ash (ash content of 34.43%) of the Saryadyr deposit, the Nadezhnyi reservoir – 65.88% SiO_2; 30.03% Al_2O_3; 1.56% Fe_2O_3; 0.14% CaO; 0.05% MgO; 0.54% Na_2O; 0.14% K_2O; 0.89% TiO_2; 0.53% P_2O_5; 0.21% SO_3.

These compositions of ash are characteristic for the majority of medium and high ash coal used in the energy sector and housing services. Note that the minerals of the Shoptykol and Saryadyr deposits having 53.27 and 33.88% of metal content each together with silica make up 98.80 and 99.76% of the mass of their ash possess large metallogenic and mineral potentials. The specific capital expenditures for the development of coal deposits including the extraction, transportation and preparation of commercial coal are significantly lower than the corresponding costs for the development of oil, oil and gas and gas deposits. Consequently, the development of coal deposits with low operating costs forms an attractive

business model with a rapid turnover of capital, accelerated payback and a long-term perspective. This justifies the choice of low-grade coal as a raw material for the production of nanoenergetic materials and the creation of low-carbon nanoenergy.

Solar photoenergy whose electric generating devices can be connected to the public grid (**on-grid**) and work without such a connection (**off-grid**) uses a large number of solar cells. These elements called crystalline (85-90%) and thin-film (10-15%) silicon are made of "solar" silicon with a purity of 99.9999% (6N) per mass (solar-grade silicon **SoG-Si**) in its turn obtained from metallurgical (technical) silicon of purity of 96-98% of mass (metallurgical-grade silicon **MG-Si**). The raw material for obtaining of MG-Si is silica the content of which in low-grade coal rocks of the Saryadyr deposit is about 66% of the ash mass. MG-Si is obtained from silica by carbothermic reduction using coal from expensive wood sorts with qualitative characteristics (table 1):

Table 1 – Charcoal indicators in accordance with GOST 7657-84

Name of indicators	Brand "A"	Brand "B"
	1st grade	1st grade
1. Mass fraction of ash, %, not more than	3.0	2.5
2. Mass fraction of non-volatile carbon, %, not less than	78	88
3. Mass fraction of water, %, no more than	6	6
4. Mass fraction of coal with grains at loading sites, %, less than 12 mm	5	5
5. Mass fraction of smut, %, no more than	2	absence

For comparison with the data in table 1, we provide qualitative indicators of nanocarbon of our production replacing charcoal (table 2):

Table 2 – Qualitative indicators of nanocarbon of coal from the Saryadyr deposit

Name indicators	
1. Sizes (nano)	100-200
2. Carbon content, %	92.74
3. Ash content, %	2.16
4. Volatiles, %	3.10
5. Humidity, %	2.00

Our experience in producing of MG-Si from silicon oxide of coal ash from the Saryadyr deposit using nanocarbon of our own production from the same Saryadyr coal showed a threefold decrease in cost, up to 4N (99.99% by weight) growth in purity, practical removal of phosphorus and sulfur oxides creating processing problems in obtaining of SoG-Si from MG-Si. Thus, low-grade coal rocks become the real raw material base for photo-energy which is an effective sector of the nanoindustry.

In addition, nanoelectronics uses a large volume of 9N pure electron silicon (electronic-grade silicon **EG-Si**) produced from SoG-Si by the Siemens method of high purification. Consequently, the production of electron silicon which forms the basis of nanoelectronics acquires a complete and competitive technological chain guaranteed by raw materials.

Kazakhstan spending more than 0.5 kg of energy carrier in oil equivalent to produce gross domestic product of one US dollar is in the top ten of the most energy-wasteful countries in the world. According to this indicator, Kazakhstan is behind Japan by 19 times, the European Union by 7 times and its partners in the Customs and Eurasian Economic Unions, Russia and Belarus, by 1.5 times [6,7]. Consequently, the solution of the issue of an affordable, cheap, alternative energy source on renewable sources and energy carriers with a low carbon content is of paramount importance for Kazakhstan and the whole world.

Usually, nanoenergetics is understood as the creation of energy generating devices and the production of energy on renewable energy sources, regenerated nanofuel cells, radiation concentrators, production of various energy storage devices on nanomaterials and others [1-8]. Therefore, we are turning to a new

aspect of nanoenergetics using hydrogenated nanocarbon as an energy carrier with a low carbon content and high electromagnetic energy of the electron shell of carbon atoms. It creates a niche for the environmentally friendly and high-calorific liquid coal fuel which is comparable to natural gas in qualitative parameters, safe and convenient in storage and transportation, and significantly cheaper than gas. Its high calorific value is provided by hydrogen. Nanocarbon and carbon atoms play the role of a catalyst and promoter of the combustion process. In addition, the main product of combustion is water condensed steam which produces additional thermal energy for the necessary heating of liquid coal. It should be noted that such a fuel having an internal oxidizer in the form of an oxygen hydroxide uses a minimum amount of atmospheric air and forms a much smaller number of nitrogenous compounds when burned.

Thus, the sectors of nanoindustry, the production of nanoenergetic materials and low carbon nanoenergetics obtain a single raw material base in the form of low-grade coal rocks and turn the coal industry into the real economy sector. Let us consider the question of the technological basis of the named sectors of the nanoindustry and their unity from the point of view of physical, physicochemical and chemical laws of the material world.

Technological base of nanoenergetic materials production and creation of low-carbon nanoenergetics. Nanoindustry and energetics are sharply distinguished by increased energy consumption and resource dependence respectively in the global economy. If the energy costs in the young and growing nanoindustry are compensated by its other advantages and can be overcome in the near future due to alternative energy sources, then the situation in the energy sector turns out to be quite different. Energetics, a basic industry responsible for the energy and environmental safety of the world economy, needs fundamental structural and resource transformations. ***Such transformations should ensure the transition of the world economy from its natural resource form to a cyclic form on alternative to coal and hydrocarbons energy sources accessible to everyone and everywhere, having higher calorific value, ecological cleanliness and ease of transportation and storage than natural gas.***

Based on the position of full use of the potentials of low-grade coal rocks there are ***two operational options for the technology of vacuum-wave conversion of coal rocks by the magnetoelectric field:***

– dry conversion with the production of carbon nanopowders, metal oxides and without the production of liquid coal fuel (**LCF**);

– hydroconversion with the production of metal oxide nanopowders and LFC for energetics.

The technology of vacuum-wave conversion of coal and hydrocarbon compounds by the magnetoelectric field, low-temperature and acoustic-wave effects is patented [8]. The main nanomolecular reactors that implement the conversion are also patented [9, 10]. The technology is implemented by a technological line that meets the requirements of technical specifications TU 3689-001-38281705-2012 [11] approved by the Federal Agency for Technological Regulation and Metrology of the Russian Federation. It is certified according to the international standard ISO-9001-2008 and has the Certificate of Conformity of the Russian Federation №C-RU.AG98.V.05607-TP 1457858 [12].

Coal rocks as a whole and low-grade coals in particular have multi-level heterogeneity with clearly distinguishable organic and metal-mineral constituents. According to the most adequate concepts [13] and images obtained by atomic force (SMM - 200T), scanning (SEM) and transmission (TEM) electron microscopes and X-ray diffractometer organic matter consists of non-condensed and condensed aromatic (benzene) and branched aliphatic structures [14]. Each of these structures forms pronounced **crystalline** (packet) formations with metal-mineralogical inclusions. From 3 to 7 layers with thicknesses from 1.8 nm to 4.8 nm, and the packets (crystallites) have porous-fractured structures with micro-nanopores with linear dimensions from 10^{-6}m to 10^{-9}m and a concentration from 10^{11} up to 10^{20} units in one cm^3 [14]. The characteristic values of the resistance of coal rocks to deformations do not exceed 1.5-1.7 MPa, and the coefficient of their strength (grinding ability) does not exceed 1.6 [13-15].

Condensed and unfused benzene nuclei constituting crystallites are interconnected by aliphatic threads with (C-C) bonds, weakened (C-O), (C-S), (S-S) bonds. The intercrystalline large-pore space is filled with coal gas-methane under high pressure of several tens (sometimes hundreds) of MPa and large mass. They are classified as volatile substances comprising from 30 to 40% of the mass of coal rocks. Low-grade coals have tremendous calorific value and can be considered a competitive energetic fuel due to them. Moreover, about 40% of the energy produced in the world (electrical and thermal) comes from coal's share (mostly low-grade). The resulting ash dumps await the arrival of nanotechnology and the formation of nanoindustry.

And so, coal has a characteristic chemical composition the substances of which formed crystalline formations with a layered structure of benzene nuclei and aliphatic hydrocarbons with numerous metal-mineral inclusions interconnected by electromagnetic forces. Single crystals and their agglomerates are speckled with a large number of cracks and micro-nanopores, other weakening and surface ruptures. These features of the chemical composition and structure, the electromagnetic nature of the interaction of atoms and coal molecules constitute the basic physical, physicochemical and chemical mechanisms obtaining nanomaterials and liquid low-carbon fuel of wide industrial use. These mechanisms form the technological basis of the process of vacuum-wave conversion of carbon and hydrocarbon compounds into materials and products. The arising question is how these basic mechanisms are used in the implementation of the conversion process. Answering the question we note that the coal rock withstands very large compressive forces (tens of MPa) and resists weakly the tensile forces. Consequently, the vacuum and vacuum stretching will have a far greater effect than compression. The natural way to create tensile forces is to transform static pressure into dynamic pressure according to the Bernoulli law [16, 17].

With this in mind, we consider the physical and mechanochemical aspects of forming nanosized particles of coal rocks and the electromagnetic laws of this process in a rotating electromagnetic field with an angular velocity from 50 rev/sec to 3000 rev/sec. Consequently, the linear velocity at the chamber wall with a radius of 200 mm (0.20 m) and at a radius of 150 mm (0.15 m) can reach$V_{0.2}$=480 m/s and $V_{0.15}$=360 m/s respectively. With an average density of coal rocks ρ_a equal to 1600 kg / m^3 the dynamic pressure has a value of $P_{0.2}\approx$184 MPa on the wall and $P_{0.15}\approx$10 MPa on a radius of 0.15 m. The layered distribution of velocities and the associated dynamic pressures indicate that the rocks are experiencing, firstly, the tensile forces of the advance layer on the layers lagging behind it; secondly, stress of at least 100 MPa is applied vertically on each layer while the reactor is also placed vertically. Rocks having a weak resistance to tensile forces begin to break down along the cracks and form new nanopores and microcracks in their smaller pieces; the process of closing the pores proceeds under the action of dynamic pressure. The gases contained in them participate in microexplosions destroying the rocks, and new nanopores and microcracks are created in their fragments [18].

Therefore, the mechanochemical regularities of Rehbinder effect manifest themselves at the initial stage of the formation of particles with micrometric and nanometric sizes [18]. The factor determining the effectiveness of obtaining carbon and oximetallic nanopowders are the electric and magnetic fields of the electromagnetic interactions of particles forming surfaces of new nanopores and microcracks. Nanopores, microcracks and freshly created surfaces limiting them are formed as a result of breaking (C-C) bonds over the entire surface. Since (C-C) bonds are formed by electrons and its carbon atoms have opposite charges with the Coulomb interaction between these atoms the opposite charges concentrate on the walls of nanopores with the surface charge density ρ_e per unit surface area. Assuming that the pores have spherical radius of $r_p=10^{-6}$ m (1 micron) we calculate ρ_e for the radius of one carbon molecule C_2, $r_c=1.243A^0$ [16]. Density $\rho_e=10^{15}$e/cm^2 for the above values. Similar calculations for silicon, aluminum, iron and titanium give average values of ρ_e on the order of 10^{14} e/cm^2, and it is on the order of 10^{15} e/cm^2 for sulfur, fluorine and phosphorus.

Note that ρ_e on the order of10^{14}–10^{15} e/cm^2 is a sufficiently high concentration of charges capable of creating an electric field with a strength of about E=10^7V/cm (10^9V/m) for the known values of length $l_c=0.771\cdot10^{-8}$cm of the chemical bond between the atoms of the carbon molecule and the energy difference of the latter and its neighboring electronic levels U_e=0.08 eV [19]. An electric field with a specified intensity is able to pull out not only surface electrons, but also ones from shallow depths, forming their emission fluxes and giving them sufficiently high energies. Therefore, taking into account that the opposite charges are separated and provide a potential difference on the newly formed surfaces it is necessary to calculate the voltage U of the field in accordance with the Coulomb law for the pore radius: it will have a value of the order of 10^5V [20]. It can be considered as an accelerating voltage, accelerating the emission electron to a velocity of about $1.875\cdot10^8$ m/s. The accelerated emission electron has a kinetic energy T_e of about 10^5 eV and emits electromagnetic waves (photons) with a length of ~ 10^{-2}nm and a frequency of ~ 10^{19}Hz. These high energy electrons and the photons emitted by them are involved in the further destruction of high-molecular compounds of coal rocks and having a sufficient intensity of the wave they crush the rocks to nanosized particles.

The truth of our findings must be experimentally verified. In this regard, we note that the Committee for Inventions and Council of Ministers opened under the USSR entered the State Register of Discoveries of the USSR on June 7, 1984 for No. 290 with a priority of December 3, 1952, the scientific discovery of the authors - B. Deryagin, Corresponding Member of the USSR Academy of Sciences, N.A. Krotov, Doctor of Chemistry, and V.V. Karasyov, Candidate of Physics and Mathematics, from the Institute of Physical Chemistry of the Academy of Sciences of the USSR with the discovery formula: ***"Previously unknown property is experimentally established for freshly formed surfaces of solids to emit high-energy electrons in a vacuum due to the separation of opposite charges during the formation of juvenile surfaces resulting in the appearance of strong electric fields of intensity up to 10^7V/cm"*** [21].

The experimental values of l_c and U_e have been used during calculation of the electric field strength. Therefore, the intensity of 10^7V/cm is an absolutely reliable value. The pore radius value obtained from electron microscopic studies of the porosity of coal rocks was used at determining of the surface density of charges ρ_e and field voltage. Moreover, the values we calculated for ρ_e, the energies of the emission electrons and the lengths of the frequency of electron emissions have coincided with their experimental data from the abovementioned discovery.

The selected value of the pore radius can be used in the calculations of the characteristics of the magnetic field per segment of pore radius from 10^{-9} to 10^{-6}m. Then the magnetic field strength **H** for the pores has values from $2.4 \cdot 10^6$ to 2.4 A/m respectively. Magnetic induction **B** ranges from 3 to $3 \cdot 10^{-2}$ T; pressure of the field P_m ranges from $3.6 \cdot 10^5$ to $3.6 \cdot 10^{-5}$ N/m^2, i.e. from 0.36 MPa to 0.3 μm Hg (a fairly deep vacuum). The creation of a vacuum by the magnetic field inside the pores with a radius of 10^{-6}m is ***not a random, but a regular phenomenon.*** According to the discovery formula (see above), the emission of electrons occurs in a vacuum. Consequently, the electric and magnetic fields of charged particles which inhabit the surface and near-surface layers of pores work together performing their own functions [20].

In general, the formation of nanopowders of carbon, metal oxides and minerals is due to the abrasion of coal rocks. Its mechanism combines mechanochemical effects, the effects of shock waves, vacuum, electric and magnetic fields. The abrasion of coal rocks into nanopowders is a chemical reaction of breaking chemical bonds between atoms characterized by the transformation of the electron shells of molecules and the electron-nuclear magnetic interaction of atomic nuclei, ions and radicals ***where electromagnetism plays the main role*** and the mechanochemical effect together with the effects of shock waves and vacuum are clearly explained by electromagnetic interactions.

Calculations of the surface density of high-energy electrons, the strengths of their electric and magnetic fields and the complete coincidence of their values with experimental data from numerous experiments prove that the radius of nanoparticles serves as a critical technological parameter determining chemical and physical activity, reactivity and degree of concentration of electromagnetic energy in nanomaterials. The mutual correlation of the radii of nanopores and nanoparticles confirms the energy efficiency of producing nanomaterials from coal. Therefore, we can formulate that we have discovered a previously unknown phenomenon consisting in the concentration in these freshly-formed surfaces of the internal energy of a large amount of electric and magnetic fields of bare electrons released even with weak effects on electrons by external electric and magnetic fields and low-intensity shock and acoustic discharges.

To provide closeness and completeness of the presentation we will specify the calculated relations. **The electric field strength $E(C_2)$** of a single carbon molecule C_2 is expressed by the formula $E(C_2)=\Delta U(C_2)/eL(C_2)$, where $\Delta U(C_2)$ is the energy difference of the latter (external) and subsequent energy levels of the C_2 molecule, $L(C_2)$ is the length of its chemical bond, and **e** is the electron charge. Their reference values are: $\Delta U(C_2)=0.08$ eV; $L(C_2)=0.771 \cdot 10^{-10}$m; $e = 1.602 \cdot 10^{-19}$C [16, 22]. Substituting this data into the indicated formula we will have the value of $\mathbf{E(C_2)=1.04 \cdot 10^9}$ **V/m** or $\mathbf{E\ (C_2) \approx 10^7}$ **V/cm.** It should be noted that the strength is a characteristic of the electric field of the molecule and does not depend on the cracking factor, and the voltage of such field is increased as a result of the formation of cracks and pores. Therefore, it is a function of the radius of cracks and pores by which we mean the radius r_s of the minimal sphere that completely covers the crack (pores): $U_e(r_s)=(e/4\pi\varepsilon\varepsilon_0) \cdot r_s^2$. Here $\varepsilon=1$, $\varepsilon_0=(1/\pi) \cdot 9 \cdot 10^9$ (F/m) is the dielectric constant. We specify that we understand fractures in the medium coming out to the surface by cracks and closed internal fractures by pores. From energy considerations, it is clear that the concentration of nanopores in a unit volume is much greater than the proportion of

micropores with radii of 10^{-6}m. This means that coal having micro-nanopores from 10^{11} units to 10^{20} units in one cubic centimeter of its volume concentrates huge tension and tremendous energy for doing useful work.

Using the above formula we calculate the voltage values for pore radii of 10^{-6}, 10^{-7}, 10^{-8}, 10^{-9} m: $U_e(10^{-6})=1.44\cdot10^3$ V; $U_e(10^{-7})=1.44\cdot10^5$ V; $U_e(10^{-8})=1.44\cdot10^9$ V; $U_e(10^{-9})=1.44\cdot10^{11}$ V. These voltages have accelerating effects on the emission electrons pulled by the abovementioned electric field strength $E(C_2)$. The velocity of the emission electrons moving under the action of the voltage $U_e(r_s)$ is expressed by the formula $U_e(r_s) = \sqrt{\frac{2e}{m_e} * U(r)}$, where $m_e=9.108\cdot10^{-31}$kg is the electron mass. Its kinetic energy is $T_e(r_s) = (1/2)m_eU_e^2(r_s)$. Using them, we calculate the velocity and kinetic energy of the emission electron at $r_s= 10^{-6}$ and $r_s=10^{-7}$ m: $U_e(10^{-6})=1.875\cdot10^7$ m/s; $T_e(10^{-6})=1.442\cdot10^3$ eV; $U_e(10^{-7})=1.875\cdot10^8$m/s; $T_e(10^{-7})=1{,}442\cdot10^5$eV. These classical formulas cease to work for other values of the pore radius since quantum effects appear. This does not mean that our reasoning is not true for them. They are true, but you need to use the apparatus of quantum physics and quantum chemistry. Since it is enough for us to show general effects that integrally express the entire electromagnetic picture of the process we remain within the framework of classical physics and chemistry [19, 22].

We emphasize that all chemical processes including chemical reactions are the essence of the electromagnetic interactions of atoms, an atom with a molecule, and a molecule with molecules. The gravitational interaction is 10^{42} times less than the electromagnetic interaction at the atomic-molecular level, and there are neither strong nor weak interactions. In other words, electromagnetism is the only interaction in obtaining nanopowders [19].

The emission electrons with kinetic energies $T_e(10^{-6}) \approx 10^3$eV and $T_e(10^{-7}) \approx 10^5$eV are used in X-ray equipment and γ-flaw detection of substances to form a stream of X-rays and γ-particles having a length and wave frequency: $\lambda(10^{-6})=1.241\cdot10^{-11}$m; $\nu(10^{-6}) = 2.418\cdot10^{19}$Hz; $\lambda(10^{-7})= 1.241\cdot10^{-13}$m; $\nu(10^{-7})=2.418\cdot10^{21}$Hz [17, 23]. Length and frequency of the scattering wave from an electron known from the experiment Compton: $\lambda_e=2{,}426\cdot10^{-12}$m; $\nu_e=1.236\cdot10^{20}$Hz can be easily obtained by standard arguments: $E_e=mc^2=8{,}186\cdot10^{-14}J=h\nu_e$ or $\nu_e=E_e/\lambda$, where $h=6.625\cdot10^{-34}$J·s is the Planck's constant and $c=2.998\cdot10^8$m/s is the speed of the photon. Hence, $\mathbf{\nu_e=1.236\cdot10^{20}Hz}$ and we obtain $\mathbf{\lambda_e=2{,}426\cdot10^{-12}m}$ from the formula $c=\lambda_e\nu_e$. Considering that the Compton effect as the elastic scattering of X-rays and γ-rays by free or weakly bound electrons is accompanied by an increase in the length of the indicated rays [23] we can conclude a complete agreement of the process we described and the known experimental facts. This demonstrates the validity of our reasoning and indicates the source of energy that contributes to the technological process and its energy efficiency. Freshly formed surfaces are in a nonequilibrium state characterized by surface charge density (bare electrons). It is known from the experiments that their concentration is about 10^5 CGSE/cm^2. Recalculating it for the number of electrons with charge in the pendants we have $\mathbf{\kappa_e\sim10^{14}e/cm^2}$. This is the experimentally determined number of electrons per each square centimetre of the surface of the discontinuities in solids.

Consider the issue of surface charge density in micro-nanopores. The surface area of individual pores is characterized by values on the order of 10^{-18}m^2 to 10^{-12}m^2. Above, we indicated the reference value of the bond length of the carbon molecule $L(C_2)\sim0.771\cdot10^{-10}$m. Therefore, in a spherical layer with a diameter of $\mathbf{4.626\cdot10^{-10}m}$ (three diameters of C_2) cut from a sphere of radius $r_s\sim(10^{-9}\div10^{-6})$ m there can be one molecule of C_2. Such a segment has a surface area of the order of 10^{-18}m^2. Then, there can be located maximum $(10^{-18}\div10)^{-12}$m$^2/10^{-18}$m^2 between one and 10^6 segments on one surface of the pores. Since the area of 1 cm^2 accommodates $\boldsymbol{\kappa}$ units of single pores with radii $r_s\sim (10^{-9}\div 10^{-6})$ m their number will be: $\kappa=1$ cm$^2/ (10^{-18}\div 10^{-12})$ m$^2=(10^{14}\div 10^8)$ units. Then the maximum concentration or surface charge density is $10^{14}\times1$ or $10^8\times10^6$ on 1 cm^2, i.e. $\mathbf{\kappa=10^{14}e/cm^2}$. In other words, the experimentally determined $\boldsymbol{\kappa_e}$ and its calculated value $\boldsymbol{\kappa}$ have the same order. The coincidences of the theoretical and experimental values of the main characteristics of the electric field of a carbon molecule located on the surface of nano-micropores such as tension, voltage, surface charge density prove the adequacy of the constructed model of coal rocks and the formation of fresh pores in them as a result of reactor abrasion. Particles of hard rocks (silicon, iron, and titanium) play a special role in the attrition of coal to powder.

Maxwell-Lorentz electrodynamics [17] brings together magnetism and electricity. This is a consequence of Ampere's hypothesis of molecular current which states that a moving electric charge creates a

magnetic field. There are different opinions about this hypothesis, from full approval to categorical refusal. Nikola Tesla considers it erroneous [24], and in our opinion the Ampere hypothesis does not correspond to reality if only there is no magnetic field in superconductivity. In other words, the flow of electrical charges **without resistance,** i.e. there is a current without a magnetic field [22]. This means that the magnetic field is created by the flow of electric charges (electrons) which experience resistance from collisions with electrons and release the smallest magnetic particles from their depths and form a circular magnetic field around the conductor. Similarly, X-rays and γ-rays are generated by braking a flux of electrons on a metal plate with a kinetic energy of 10^3eV and 10^5eV respectively. It is known that these rays have great penetrating power and great intensity, but do not create an electric field. In other words, in either case, the manifestation of these particles is the same and indicates their **magnetic nature**. It follows that electrons are carriers not only of electric charges (unipolar particles), but also of bipolar magnetic particles.

We emphasize the validity of Nikola Tesla's ingenious conjecture [24] that "***speaking of electric charges, one must abandon the idea of two positive and negative charges***". Tesla states that there is neither positive nor negative charge, but there is a charge without any signs and there is its elementary carrier in terms of indivisibility and indestructibility. Similarly, there is an elementary **bipolar magnetic particle**. It is formed by an electron. This is indicated by the decay of a neutron into a proton, an electron, and neutrino particles out of which the electron is not contained in the interior of the neutron (they have different sizes). Consequently, it is formed according to a special genetic program mainly from particles ejected from the depths of the neutron.

Thus, there are an electric particle and a magnetic particle. Each of them is an independently existing particle carrying only one type of entity, electricity or a magnet respectively. They are not reduced to each other being independent entities. The lack of understanding of this point can be explained by the absence of the law of interaction of magnetic particles on coal rocks and the experimental results on these effects. Therefore, let us return to the calculations of the characteristics of the magnetic fields of a carbon molecule and its atom. Let us recall that the intensity **H** of the magnetic field determines the magnetic induction **B** and the magnetic pressure: $B=\mu_0 H$, $P=(\mu_0/2)H$, where $\mu_0= 4\pi\cdot10^{-7}$H/m is the magnetic constant. A vacuum of $3.6\cdot10^{-2}$ N/m^2 and $3.6\cdot10^{-6}$ N/m^2 is created inside the micropores with radii of 10^{-7}m and 10^{-6} m. Consequently, the magnetic tension of the magnetic field lines breaks the bonds of electrons with the nucleus. This is a very important electron emission mechanism. The Langmuir frequency [23] of a $\omega_L= (4\pi e^2\rho_e/ m_e)^{1/2}$ of the electron with a concentration of 10^{14}e/cm^2 is equal to $2\cdot10^3$Hz, its speed is equal to 10^7m/s and therefore a shock wave arises [23]. This wave has a compression and expansion phase. The latter superimposed on the magnetic tension causes a significant destructive effect. Such secondary effects undoubtedly have a role and become an element of a single mechanism of abrasion of the rock in nanopowders along with the mechanochemical effects of Rehbinder [25].

Let us consider the matter of acoustic waves accompanying the listed physical effects, external waves from a sound generator. Note the speed ν in m/s of longitudinal waves in rods of silicon is equal to (3700 ÷ 4900); aluminum – 5080; iron – 5170 and carbon – 2100. The intensity and pressure of sound waves determined by the relations $I_i=(\rho_i\nu_{ai}/2)\cdot(\upsilon_{oi})^2$ and $P_i= \rho_i\nu_{ai}\upsilon_{oi}$ are measured in (W/cm^2) and (N/m^2) [22]. In these formulas i refers to a substance (silicon, aluminum, iron, carbon), ρ_i is their density (kg/m^3), ν_{ai} is the speed of sound waves (indicated above) and υ_{oi} is the oscillatory velocity of particles of a substance under the wave action. Even if υ_{oi} is the same for all substances, then substances with different densities and velocities ν_{ai} will experience different pressures from sound waves. Substances with a higher speed of wave propagation become concentrators of sound stress and relieve these over voltages freeing themselves from the environment. In other words, their bonds with carbon are broken and they are separated from coal rocks. The orientation of carbon molecules plays a significant role with respect to the direction of wave propagation. Molecules having transverse arrangements to the direction of the wave undergo a breaking of bonds. The internal and external (superimposed) magnetic fields play an important role in their reorientation. Since carbon is a diamagnetic, it always assumes a position with the orientation of the magnetic field in the direction opposite to the direction of the vector of the external field strength. Thus, the combined actions of vacuum, external and internal electric and magnetic fields, as well as external and internal sound fields, together with the dynamics of rock movement in the reactor under the influence of a rotating electromagnetic field produce a technological process of abrasion of coal rocks and

the production of nanopowders from them. Purification of nanopowders and their separation into fractions can be done in a different way. In particular, metals can be extracted by magnetic separation since all metals including non-magnetic aluminum and titanium are magnetized in a strong magnetic field, they can be removed by a strong electromagnet. There are effective methods of hydroflotation; special heavy flotation liquids have been developed for cleaning coal from ash. Finally, there is a method for aerodynamic separation of substances according to specific gravities, so that fractional separation of powder and the production of powders of individual elements are technologically feasible and quite effective with greater purity.

The process produces a sufficiently pure carbon powder and separate fractions of powders of oxides of silicon, aluminum, iron, titanium, potassium, calcium, manganese, and magnesium which require reduction. We refer to the known technologies for obtaining these substances in a reduced form [25, 32, 33].

Turning to low-carbon nanoenerg based on structured nanomaterials we will not consider photoenergy and other types of energy based on renewable energy sources (RES) including hydrogen and controlled thermonuclear energy. We will explore only the energy associated with coal and carbon. A large amount of liquid pyrolysis waste and a certain amount of coal dust are formed during the processing of highly coking coal to coke. Usually, one ton of coke, one ton of liquid pyrolysis waste and about one ton of hydrocarbon gases with coal dust are obtained when processing 3 tons of coal. These gases after cleaning are used for production needs, and coal dust is dumped [25, 32, 33]. Coal dust practically not having volatile combustible substances (gases) and being a hydrophilic substance is strongly moistened with atmospheric moisture. Therefore, it is poorly amenable to gasification and its direct use as an energy fuel. However, coal dust is a pure carbon material. Therefore, we obtained technical nanocarbon from the material having a wide industrial application at a low cost. The use of this nanocarbon in other sectors of the economy other than energetics will be considered specifically.

Liquid pyrolysis wastes called coke chemical (**CCW**) and stored in unqualified earthen barns create a formidable environmental problem. This is evident from the chemical composition of its liquid part which is about 60% of the mass, and the rest (about 40%) of the CCW is coal dust and coke. The CCW using the vacuum-wave hydroconversion technology is processed in a matrix of highly ionized water (plasma state) constituting 40% of mass of the CCW into liquid carbon fuel (LCF) with a low carbon content.

Let us give the chemical composition of the CCW obtained by the gas-liquid chromagraphic mass spectrometry method (table 3).

From table 3, we can see the presence of a number of toxic compounds such as benzene, phenol, naphthalene, phenanthrene and others. The bulk of the liquid part of the CCW is made up of aromatic compounds with benzene rings of condensed and unfused nuclei which require high energy costs at break, straightening and hydrogenation. Such a technological process is carried out by the technological line of the vacuum-wave conversion of the CCW with the addition of highly ionized water (**HIW**) in the plasma state [26-31]. The HIW is introduced into the CCW in a nanodispersed state. It is in the form of exfoliated nano-inclusions and does not precipitate even during long-term storage (up to six months). HIW performs several functions: having a conductivity greater than carbon it electropolarizes the whole medium; having a higher dielectric constant than carbon it concentrates a huge amount of current line in its nano-droplets; when a certain critical number is exceeded these lines of currents mutually pushing away like parallel conductors break the nanodrops into hydrogen and hydroxide. In other words, HIW becomes a donor of hydrogen that participates during the life of its individual atoms and OH molecules for ($10^{-12}\div 10^{-10}$) seconds in the process of intensive hydrogenation and saturation of carbon molecules with hydrogen by hydrogenation and the formation of primary monohydric alcohols from C_3 to C_{12} and up. These microexplosion processes are even more intense when HIW drops have diameters of several tens of microns, and which has been found experimentally. Another fact has been established: coke and dust particles are activated and fully hydrogenated forming liquid carbon fuel with a high degree of hydrogenation. In fact, 40% of the HIW mass is assimilated as H and OH. This is an industrially implemented indicator of HIW digestibility by coke chemical waste. The obtained low-carbon fuel is certified as **hydrogenated energetic fuel TGE-40** (Russian trademark officially introduced in 2012).

It was possible to bring the proportion of HIW in the fuel to 72% of the mass under laboratory conditions, and its upper limit of 80% and higher was theoretically proved. This means the possibility of creating of low-carbon (less than 10% mass) nanoenergetics based on nanocarbon with the role of a

Table 3 – Chemical composition of CCW

No	Retention time, min	Peak area	Compound	%
1	5.4	758 799	Toluene	2.55
2	16.1	231 029	Phenol	0.78
3	16.3	51 569	Pyridine, 2,4,6-trimethyl-	0.17
4	17.6	111 497	Benzene, 1-ethynyl-4-methyl-	0.37
5	17.8	82 902	Phenol, 2-methyl-	0.28
6	18.2	263 311	Phenol, 4-methyl-	0.88
7	20.5	8 518 028	Naphthalene	28.59
8	21.8	469 919	Quinoline	1.58
9	22.2	1 482 402	Naphthalene, 2-methyl-	4.98
10	23.5	408 287	Biphenyl	1.37
11	23.7	128 100	Naphthalene, 1,6-dimethyl-	0.43
12	24.8	877 090	Biphenylene	2.94
13	25.2	618 351	Acenaphene	2.08
14	25.5	807 529	Dibenzofuran	2.71
15	26.5	1 586 800	Fluoren	5.33
16	26.7	96 772	9H-Xanthene	0.32
17	26.9	142 231	Dibenzofuran, 4-methyl-	0.48
18	27.0	65 071	1,1'-diphenyl, 2.2 ', 5.5' -tetramethyl-	0.22
19	28.8	80 278	Dibenzothiophe n	0.27
20	29.2	3 624 895	Phenanthrene	12.17
21	29.3	939 011	Anthracene	3.15
22	30.1	279 543	Carbazole	0.94
23	30.2	249 992	Anthracene, 2-methyl-	0.84
24	30.7	271 220	4H-cyclopenta phenanthrene	0.91
25	32.3	2 662 912	Fluorantene	8.94
26	32.6	1 852 582	Pyrene	6.22
27	32.7	141 079	Benzo [b] naphtho [1,2-d] furan	0.47
28	33.7	99 888	7H-Benzo [c] fluorene	0.34
29	33.7	398 178	11H-Benzo [b] fluorene	1.34
30	35.7	108 593	Benzo [b] naphtho [1,2-d] thiophene	0.36
31	35.8	171 811	Cyclopenta [CD] pyrene	0.58
32	36.0	82 648	Naphtho (2,1-e) quinoline	0, 28
33	36.5	805 914	Benzo [a] anthracene	2.71
34	36.8	435 160	Triphenylene	1.46
35	37.1	98 931	Benzo (s) carbazole	0.33
36	42.6	788 828	Benzo [K] fluoranthene	2.65

catalyst and promoter of the production process of forming a fuel in a TGE. Nanocarbon is active during the first few months of life since its production, especially in the first few days. Therefore, it is desirable to combine the production process of LCF with the process of obtaining of nanocarbon integrating into a single technological chain.

Industrial and laboratory bench tests of TGE-40 showed its high calorific value [30, 31] with a calorific value of 12783 (kcal/kg) comparable to that of natural gas and greater by 25÷30% than that of heating fuel. Consequently, it completely replaces both natural gas and furnace fuel, and, moreover, furnace energy and ship fuel oil of petroleum origin. The environmental performance indicators of LCF are not inferior to natural gas and are significantly better than those of petroleum fuels including the maximum permissible concentrations (MPC) and emissions (MPE). Having an internal OH oxidant in alcohol compounds it has a lower consumption of atmospheric air and differs from natural gas in terms of emissions of nitric acid compounds for the better (lower by 30%). Due to the high content of hydrogen the temperature of combustion of LCF reaches up to 2300 and can provide long-flare combustion which is so necessary for many technological processes. Special videos were shot on burning LCF through nozzles, in drying ovens, boilers including energy boilers and on their use in diesel generators of electrical energy.

LCF has a kinematic viscosity of (8÷12) cSt (centistokes) at +20°C, a pour point below –27°C and a flash point above +60°C. These rheological indices allow transportation of fuel and air generators in road and rail tankers, by tanker and by pipeline. It is safer for transportation and storage than natural gas, less fire-explosive than the latter and does not contain mercaptans and hydrogen sulfide. In contrast to natural gas, LCF can be used in all types of stationary and mobile power plants, ships and ship gas turbine plants as gas turbine fuel.

The transition to the low-carbon nanoenergetics transforms coal into a wide resource base. It can be oriented to all kinds of industrial waste from plastic plants, acid tars, granary and other sludge, transformer, industrial, motor, hydraulic and other types of used oils. This could include spent rolling oils from steel and other steel mills. Their environmentally friendly recycling can be carried out by hydroconversion technology using carbon nanopowders, urban and industrial wastewater. Similarly, it would be possible to solve the problem of disposal of oil-contaminated water and soil.

Discussion of results. Strictly speaking nanotechnology as an applied direction of modern science is neither a supernatural nor a new miracle. Its essence lies in the discovery, recognition and use of the properties of matter, characteristic of its nano-sized components, as well as in the accumulation of new knowledge about matter, the interactions of its parts and on this basis reaching a higher level of cyclic, recycled waste of natural resources with its gradual decrease. Speaking about the properties of nanoparticles it is necessary to investigate the natural mechanisms of formation and renewal, for example, cells of living organisms or the formation of fossil energy carriers (oil, natural gas and coal).

Giving examples the organic compounds where the carbons between themselves and the atoms of other elements are chemically very strongly bound are involved in controlled and high-speed reactions in very harsh, energy-consuming conditions [25, 32, 33]. However, their measured, calm and steady state in a living cell disappears quickly under the action of enzymes (biological catalysts), and the biochemical reactions of their transformation are accelerated hundreds of millions and billions of times, as well as with mild conditions that do not threaten the functioning and life of organisms. The study of these biochemical processes has revealed patterns and their application in the sphere of tautomeric transformations of carbon in inanimate nature with speeds that are as many times as high as the above rates of biochemical processes. The tautomeric transformations of carbon which constitute a narrow area of their transformation under mild conditions (+ 25°C) are in progress with the breaking of old and the formation of new bonds in the form of a substitution reaction and the transfer of a group of atoms with dimensions of several decimal and hundredths of a nanometer. Another example is associated with chemically passive molecules of saturated hydrocarbons, but capable of activation and rapid reaction by the formation of coordination compounds with transition metals [25, 32, 33]. Nanopowders of the latter with sizes less than 10 nm ensure the flow of selective catalytic reactions with the synthesis of a wide range of organic compounds including methane under mild conditions and the lowest energy costs. Examples show the presence of a nanotechnological alternative to natural opportunities, and the results we have outlined are the presence of a nanotechnological alternative to resources, energy, and natural opportunities in general.

Citing examples of high technology in animate and inanimate nature we did not pursue the goal of opposing nanotechnology to other technologies, but only wanted to emphasize the need to take nature prompts into account. One of these clues is the high ash content of coal. The highest content in ash belongs to silicon oxide which has the highest chemical clarke (16.35% in nature). Then comes alumina with the highest (4.99%) chemical clarke among metals. It is known from chemistry that crystalline aluminosilicates called zeolites and formed from silicon and aluminum oxides are the most effective catalysts for the hydrogenation reaction of unsaturated hydrocarbon compounds, especially aromatic [32, 33]. At the same time, the active role belongs to the cations of alkali and alkaline-earth metals that are part of the zeolite. Considering the chemical composition of the ash we can see the participation of alkali metals in it; for example, sodium or potassium. Therefore, we can say that the sol played an active role in the formation of coal rocks where there was no access of oxygen and moisture from the outside and the internal moisture was used for hydrogenation processes of formation of volatile gases, mainly methane, and in an energy-efficient way to create aromatic hydrocarbons condensed and unfused benzene rings. Of course, in our case, zeolites could function as a catalyst and participate in the process of vacuum-wave conversion and hydroconversion of carbon and hydrocarbon compounds to final products that are close to equilibrium, even saturated and supersaturated hydrogen and OH compound. Since there is no sharp difference in the exact boundary between acid-base and redox reactions zeolites can also participate effectively in the reduction of silicon, aluminum, other metals and minerals from the composition of coal ash.

Thus, coal rocks contain natural zeolite catalysts that are necessary for hydrogenation and the production of low carbon liquid fuels. This opens up new opportunities in the formation of nanoindustry. We have developed a technological line for the production of pure and highly pure carbon nanopowders, oxides of silicon, aluminum, iron and titanium on the basis of the technology of dry conversion of coal rocks into nanopowders. Pure nanocarbon and silicon oxide are the main materials in the manufacturing of electrical insulation and rubber products. Pure nanocarbon can be used as an additive in a road bitumen to improve of an asphalt concretes strength [34, 35]. Silicon oxide in the recovery and purification gives technical grade silicon MG-Si which is produced from SoG-Si.

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НОНАЭНЕРГЕТИКАЛЫҚ МАТЕРИАЛДАР МЕН ТӨМЕН КӨМІРТЕКТІ НАНОЭНЕРГЕТИКА: ЗАҢДЫЛЫҚТАР, ТЕХНОЛОГИЯЛАР ЖӘНЕ ШИКІЗАТ

Аннотация. Төмен сұрыпты көмір жыныстарының құрамына кіретін заттардан (көміртектен, металл тотығынан, тұздардан және минералдардан) алынатын энергиялық тиімді келесі материалдар өндірісінің физикалық, физика-химиялық және химиялық заңдылықтары ашылды, зерттелді және негізделді:

– наноэнергетикалық материалдар (нанокөміртек, кремнийдің, алюминийдің, титандың, темірдің, марганецтің, магнийдің және т.б. наноұнтақтары);

– төмен көміртекті сұйық жанармайдың, экологиялық таза, калориясы жоғары сапа параметрлері бойынша табиғи газбен салыстыруға болатын, бірақ, қауіпсіз, бағасы тарапынан арзан және газбен салыстырғанда тасымлдау және сақтау тарапынан ыңғайлы. Жыныстар тозуының, микрожарықшақтар және нанокеуектер нанобөлшектерінің өлшемдері наноэнергетикалық материалдар өндірісінің энергиялық тиімділігінің және төмен көміртекті наноэнергетиканы дамытудың сыни технологиялық параметрлері болып табылатыны анықталды.

Түйін сөздер: төмен сұрыпты көмір жынысы, күлділік, микрон-наноөлшемдердің жарықшақтары мен микрокеуектері, физикалық өріс, вакуум, сиретілудің соғылу толқындары, гидроконверсия, құрғақ конверсия, ішкі және сыртқы электр және магнит өрістерінің кернеулігі.

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НАНОЭНЕРГЕТИЧЕСКИЕ МАТЕРИАЛЫ И НИЗКОУГЛЕРОДНАЯ НАНОЭНЕРГЕТИКА: ЗАКОНОМЕРНОСТИ, ТЕХНОЛОГИЯ И СЫРЬЕ

Аннотация. Открыты и изучены физические, физико-химические и химические закономерности и обоснована технология энергоэффективного производства из веществ (углерода, окиси металлов, солей и минералов), входящих в состав низкосортных угольных пород:

– наноэнергетических материалов (наноуглерод, нанопорошки кремния, алюминия, титана, железа, марганца, магния и т.д.);

– низкоуглеродного жидкого топлива, экологически чистого, высококалорийного сопоставимого по параметрам качества с природным газом, но безопасного, значительно дешевого по цене и удобного при транспортировке и хранении в сравнении с газом. Установлено что размеры наночастиц истирания, микротрещин и нанопор пород являются критическими технологическими параметрами энергоэффективности производства наноэнергетических материалов и развития низкоуглеродной наноэнергетики.

Ключевые слова: угольная порода низкосортная, зольность, трещины и микропоры микрон-наноразмеров, физические поля, вакуум, ударные волны разряжения, гидроконверсия, сухая конверсия, напряженность внутренних и внешних электрических и магнитных полей.

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REFERENCES

[1] Poul Ch., Owens F. Nanotechnology. Translation from English. M.: Technosphere, 2006. 336 p. (in Russ.).

[2] Gusev A.I. Nanomaterials, nanostructures, nanotechnologies. M.: Fizmat lit., 2005. 416 p. (in Russ.).

[3] Foster L. Nanotechnology. Science, innovation and opportunity. M.: URSS, 2008. 243 p. (in Russ.).

[4] Minaev A.A. Monitoring of patent documents on nanotechnology // Patents and licenses. No. 12, 2010. 94 p. (in Russ.).

[5] Nanotechnology in the coming decades. Forecast of research directions / Ed. Roko M.K., Williamsa R.S., Alivisatos P. M.: Mir, 2002. 292 p. (in Russ.).

[6] Akylbekova A., Absambetov M. Atlas of the energy potential of renewable energy sources of the Republic of Kazakhstan // Materials of the World Congress of Engineers and Scientists “Energy of the Future: Innovative Scenarios and Methods for Their Realization WSEC - 2017”. Astana, 2017. Vol. 2. P. 131-137 (in Russ.).

[7] Bobylev S.N. Low carbon energy: new challenges for the raw material model of development // Materials of the World Congress of Engineers and Scientists “Energy of the Future: Innovative Scenarios and Methods for Their Realization WSEC - 2017”. Astana, 2017. Vol. 3. P. 120-124 (in Russ.).

[8] Innovatsionnyy patent RK 11314. Innovative patent RK 11314. 2000. The method of conversion of hydrocarbons / Kalybaev A.A., Aspandiyarov B.B. (in Russ.).

[9] AS Kalybay A.A., Aspandiyarov B.B. No. 28846. Wave generator, 2000 / 0785.1. 07/14/2000 (in Russ.).

[10] AS Kalybay A.A., Aspandiyarov B.B. No. 28898. Device for wave processing of the medium, 2000 / 0786.1. 07/14/2000 (in Russ.).

[11] Specifications TU 3689-001-38281705 - 2012 Technological line for vacuum-wave conversion of hydrocarbons by a magnetic-electric field in the fuel is light, medium and heavy distillate liquid (liquid fuel: for specific processing), gasoline AI-92, AI-95, AI-98 Euroclasses 4 and 5, diesel fuel Euroclasses 4 and 5, marine fuel and hydrogenated fuel of energy grade ТГЭ-40. M.: FBU "ROSTEST - MOSCOW", 2012. 26 p. (in Russ.).

[12] Certificate of Conformity No. C-RU. AG98. B. 09607 - TP 1457858 Russian Federation: Oil Refining Equipment: technological line for the vacuum-wave conversion of hydrocarbon raw materials by a magneto-electric field and complies with the requirements of the Technical Regulations for the Safety of Machinery and Equipment (Government Decree of 15.09.2009 No. 753). 1 section (in Russ.).

[13] Whitehurst DD, Mitchell TO, Farkashi M. Coal liquefaction. M.: Chemistry, 1986. 25 p. (in Russ.).

[14] Alekseev A.D., Vasilenko T.A., Ulyanova E.B. The change in the volume of closed pores of fossil coal // Chem Solid Fuel 3. 1999. P. 39-45 (in Russ.).

[15] Eremin I.V., Zharova M.N., Skripchenko G.B. The material composition, structure and properties of fossil coal in connection with their processing into liquid and gaseous fuels // Chem Solid Fuel 4. 1978. P. 22-29 (in Russ.).

[16] Physical quantities. Reference book. Ed. Grigorieva I.S., Melikhova E.Z. M.: Energoizdat, 1991 (in Russ.).

[17] Parsel E. Berkley Physics Course. Electricity and magnetism / Translation from English. M.: Science. The main editors of physical and mathematical literature, 1983. 416 p. (in Eng.).

[18] Golosov S.M. Mechanical phenomena in superfine grinding. Novosibirsk: Science, Siberian Branch of the USSR Academy of Sciences, 1971. 216 p. (in Russ.).

[19] Ivanov V.V., Poplavko E.M., Malevsky A.Yu. Mineral raw materials. Reference book. M.: ZAO Geoinformmark, 1998. 701 p. (in Russ.).

[20] Kalybai A.A., Teltayev B.B., Abzhali A.K. Carbon and Nanoenergetic Materials // Symposium VIII. Almaty, 2018 (in Eng.).

[21] State Register of Scientific Discoveries of the USSR from 1957 to 1987. Moscow: State Committee on Inventions and Discoveries at the State Committee on Science and Technology of the USSR, 1988. 160 p. (in Eng.).

[22] Quick reference book of physical and chemical quantities / Editor K.P. Mishchenko. M.: Chemistry, 1974. 330 p. (Yavorsky B.M., Detlaf A.A. Physics Handbook. M.: Nauka, 1968. 612 p.) (in Russ.).

[23] Ivanov B. The laws of physics. M.: Higher School, 1986. 335 p. (in Russ.).

[24] Nikola Tesla. Lectures. Samara: Agni Publishing House, 2008. 312 p. (in Russ.).

[25] Khrennikov T.M. Mechanochemical activation of coals. M.: Nedra, 1993. 176 p. (in Russ.).

[26] Kalybai A.A. Energy efficient ultradeep hydroconversion of highly viscous hydrocarbons into motor fuels // Oil and gas. 2014. 1 (79). P. 45-59 (in Russ.).

[27] Kalybai A.A., Nadirov N.K. New physical and chemical principles of deep processing of high-viscosity oils // Oil and gas. 2008. 3. P. 33-44 (in Russ.).

[28] Kalybai A.A. Deep oil conversion by turbulent-wave molecular destruction // Oil and gas. 2003. 3. P. 72-79 (in Russ.).

[29] Kalybai A.A. Theory and practice of cold cracking // Bulletin of the IA of Kazakhstan. 2003. 1(9). P. 78-81 (in Russ.).

[30] Kalybai A.A. On the vacuum wave technology of deep processing of hydrocarbon raw materials // Oil and gas. 2008. 3. P. 80-89 (in Russ.).

[31] Kalybai A.A., Zhumagulov B.T., Nadirov N.K., Abzhali A.K. Alternative technology for efficient processing of crude oil // Oil and gas. 2017. 3. P. 88-102 (in Russ.).

[32] Krichko A.A., Lebedev V.V., Farberov I.L. Non-fuel use of coal. M.: Nedra, 1978. 214 p. (in Russ.).

[33] Kucher R.V., Kompanets V.A., Butuzova L.F. The structure of fossil coal and their ability to oxidize. Kiev: Naukova Dumka, 1980. 167 p. (in Russ.).

[34] Iskakbayev A.I., Teltayev B.B., Oliviero Rossi C., Estayev K. A new simple damage accumulation model for predicting of an asphalt concrete cyclic strength // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 5. P. 38-47. https://doi.org/10.32014/2018.2518-170X.8

[35] Iskakbayev A.I., Teltayev B.B., Yensebayeva G.M., Kutimov K.S. Computer modeling of creep for hereditary materials by Abel's kernel // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 6. P. 66-76. https://doi.org/10.32014/2018.2518-170X.36

[36] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[37] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[38] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[39] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[40] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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THE DIGITAL TRANSFORMATION OF THE OIL AND GAS SECTOR IN KAZAKHSTAN: PRIORITIES AND PROBLEMS

Abstract. The fourth industrial revolution precipitately spins up, including due to digital technologies, robotization of productions, the fissile introduction of cyber systems, development of the Internet of things. In the modern world, digital technologies play a more and more critical role in the development of the national economy of the countries. They have several advantages: simplification of access for the population and business to public services, acceleration of exchange of information, and the emergence of new opportunities for business, creation of new digital technologies, products. The main objective of the state program "Digital Kazakhstan" is progressive development of a national digital ecosystem for economic growth, improving the competitiveness of the economy and improvement population quality of life. According to experts, only digitalization of Oil&Gas sector will reduce manufacturing costs and accident rate, and increase the effectiveness of geological exploration, capital investments in production projects, decrease common threats. Digitalization of mines within the Digital Mine project will allow for cutting down expenses on 4%; considering marginality of the industry of 29%, the effect will be 12-26 billion KZT in 2025 and 23-40 billion KZT in 2018-2025.

Keywords: digital economy, digital transformation, Eurasian Economic Union, oil and gas sector, IoT, AI.

Introduction. Today the main agenda for the majority of the countries in the world, including the countries of the Eurasian Economic Union, is digital transformation and creation of hyper-competitive digital economy. An organizational and technological basis of the functioning of structures and institutes of the digital economy are digital platforms (for example, the IT platform on a basis a blockchain). An essential role in them is played by uniform IT architecture, uniform digital standards, IT safety and data protection. Digital platforms provide new levels of cooperation between the companies from different industries and spheres of the economy that leads to the creation of new products and services, new network communications and also new global chains of the creation of added value and obtaining network effects. In current conditions, the integrative distributed network platforms characteristic of new neural network technological way are created.

"The digital agenda" of the Eurasian Economic Union is important for the dynamic development of the digital economy in the Eurasian economic space. Successful implementation of the digital agenda and the national projects "Digital Economy" in the countries of the Eurasian Economic Union is crucial for improving the competitiveness of the countries of EAEU in the world markets in the conditions of strengthening of innovative global hyper-competition.

The Eurasian cooperation within implementation of the Digital Economy of EAEU and Digital Eurasia programs is directed to the creation of conditions for the emergence of breakthrough and perspective through neuro and digital technologies and platforms, including technologies of wireless communication, biometrics, the virtual and complemented realities, artificial intelligence, the electronic government, network safety which use is intended to provide realization of competitive advantages of the countries of the Eurasian economic space.

The digital agenda of the Eurasian Economic Union was initiated by the decision of the Supreme Eurasian economic council of December 26, 2016 No. 21 "About the formation of the digital agenda of the Eurasian Economic Union." The digital agenda of EAEU includes a circle of questions, relevant for EAEU, on digital transformation within the development of integration, strengthening of common economic space and deepening of cooperation of state members in the digital economy.

Adoption of the document "The Main Directions of Implementation of the Digital Agenda of the Eurasian Economic Union till 2025" who were approved as presidents of the countries of EAEU at a meeting of the Supreme Eurasian economic council of EAEU in October, 2017 in the Sochi became an institutional and legislative basis for implementation of the Digital Agenda of EAEU. As the initial task development and carrying out the policy coordinated with the countries of the Union in the field of development of Internet economy, the formation of the general rules of digital trade, uniform standards of exchange of information and ensuring its protection is defined. The main directions of Digital Agenda include: digital transformation of the branches of economy and cross-branch transformation; digital transformation of commodity markets, services, capital, and labor; digital transformation of processes of management of integration processes; development of digital infrastructure and ensuring security of digital processes.

The digital agenda of EAEU is a comprehensive program of digital transformation. It means improving the competitiveness of EAEU from through digital technologies and digital platforms; it is new cooperation, only in digital measurement. In total six initiatives are approved. Among them: digital trade, digital transport corridors, digital industrial cooperation, and agreement on a turn of data, the system of regulatory "sandboxes." The Eurasian economic commission created a digital design office of EAEU which will estimate and advance the offered integration projects of EAEU in the field of the digital economy. Digital transformation represents the high-quality, revolutionary changes consisting in digital transformations in a fundamental change of structure of the economy, in a transfer of the centers of the creation of added value to the sphere of forming of digital resources and through digital processes. An important initiative is the creation of the uniform digital platform of EAEU. The digital platform represents the system of means, the possibility of their direct interaction supporting the use of digital processes, resources, and services by a significant amount of subjects of a digital ecosystem and providing. Integration of digital infrastructure of the countries of EAEU which assumes not only the introduction of uniform standards but also the general management of infrastructure, the formation of full-fledged digital transport corridors is essential. Also within EAEU, it is supposed to include three critical elements in digital integration:

The EAEU of Data X is a uniform subsystem of transfer and data exchange in electronic form. It is the platform which can be used for the exchange of information, and eventually – for the exchange of legally significant protocols between private companies;

The EAEU of ID is right space of electronic trust. It includes services of identification, authentication, authorization, digital archive. It will allow issuing, for example, references to citizens of one country in the territory of another in a digital format;

The EAEU of Geo is a geographic information system and services of a cartographic basis which promotes simplification of control of transportation and traceability of goods.

Problem Statement. According to calculations of the World Bank, implementation of the common digital agenda till 2025 will bring an additional gain of cumulative GDP of EAEU to 1% a year and also 8 million jobs and economy on expenses for the business of 50 billion dollars.

In the long term institutes of the countries of EAEU are faced by a problem of creation of the Eurasian digital ecosystems and also participation information of global standards and regulations in the world digital markets.

At the beginning of 2017, the President of Kazakhstan Nursultan Nazarbayev set the task of carrying out the third modernization which core is digitalization. In Kazakhstan, the state program "Digital Kazakhstan" which was accepted and approved in December 2017 was developed. Its main goal is to provide acceleration of national economy and improvement of population life quality by digital technologies.

In the short term projects on digitalization and technological modernization of the existing branches of economy, government institutions will be implemented, to develop digital infrastructure. In the long term, the program is aimed at "creation of the digital industry of the future." It has to provide long-term

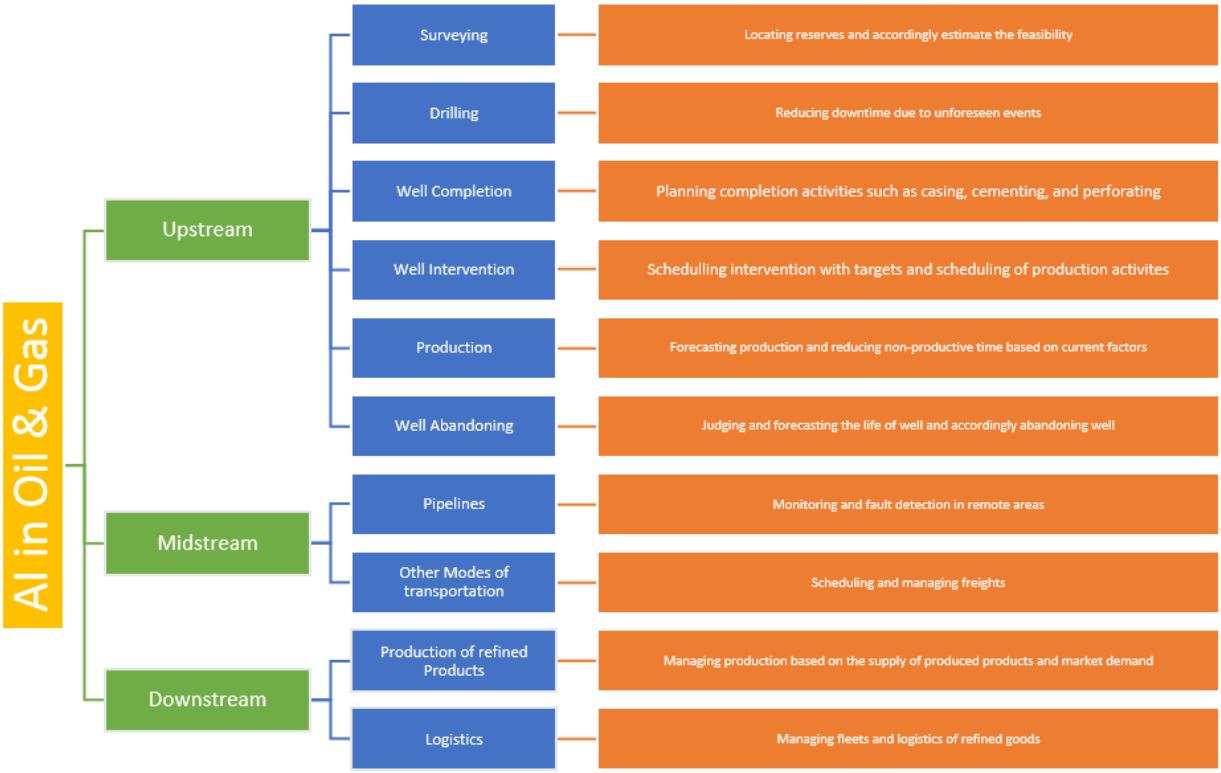
stability and start of the digital transformation of the country due to increase in the level of development of the human capital, creation of institutes of innovative development and in general progressive evolution of a digital ecosystem.

Realization of "Digital Kazakhstan" will be carried out in five key directions: digitalization of the branches of economy; transition to the digital state (concept of the SmartCity); realization of a digital Silk way; development of the human capital; creation of an innovative ecosystem.

Data Analysis. KazMunaiGas creates a new operational model, where the number of top manger will be decreased and process models will be developed for back offices. Projects are divided into two parts which include methodology and automation. According to Salov, digitalization is impossible without structural, organizational changes in the company. It is impossible to achieve results only at the expense of information systems if not to reconstruct business. The main objective is achievement that the share of processes which would be carried out using information systems equaled to 80 percent. One of the aims which the Kazakhstan oil industry workers pursue during digitalization to increase a between-repairs interval up to 600 days, now this indicator is 140-250 days. The community of engineers in an oil and gas complex defines digitalization so: it is not difficult, but it is difficult because each direction in an oil and gas complex creates digital filling in the industry which has to be used. The strategic resource of the oil and gas industry is smart technologies (IoT).

According to experts, only digitalization of Oil&Gas sector will reduce manufacturing costs and accident rate, and increase the effectiveness of geological exploration, capital investments in production projects, increase in oil recovery. Oil has various components: upstream (exploration and production), midstream (possession transport and storage of oil and gas) and downstream (oil refineries) – and AI can assist in helping in each area from advances in sensors and software to managing large amounts of collected data.

According to Markets and Markets research, Artificial Intelligence ("AI") in the oil and gas industry is expected to grow from 2017 to 2022 (USD 2.85 Billion). This growth is due to the adoption of big data technology, digitalizing the oil and gas industry through adopting a variety of predictive algorithms, analytics, automation systems and more. In 2016, ExxonMobile collaborated with Massachusetts Institute



Retrieved from https://bigdata-madesimple.com/is-ai-the-solution-that-the-oil-gas-industry-needs/

Figure 1 – AI in Oil and Gas sector

of Technology ("MIT") to create "self-learning, submersible robots for ocean exploration." These robots have the ability to detect natural seeps in the ocean floor. According to National Geographic, these seeps, or leakages, occur "when oil escapes into the water column from highly pressurized sea floor rock." Other oil companies such as Royal Dutch Shell ("Shell") are incorporating virtual assist features.

Creation of digital oil and gas innovations and technologies is generally bound to Hi-Tech ideology. The ecosystem of digital oil and gas economy is based on digital collecting and transmission of the geodata coded in discrete alarm impulses. Digitalization of collecting and transfer of geodata will be a key factor in the development of digital oil and gas production.

According to McKinsey, IoT has a total potential economic impact of 3.9 Trillions to 11.1 Trillions (USD) by the year 2025. With a potential economic impact of 930 Billions (USD) from mining and O&G companies within the next ten years, it's no surprise that the O&G industry is interested in leveraging IoT.

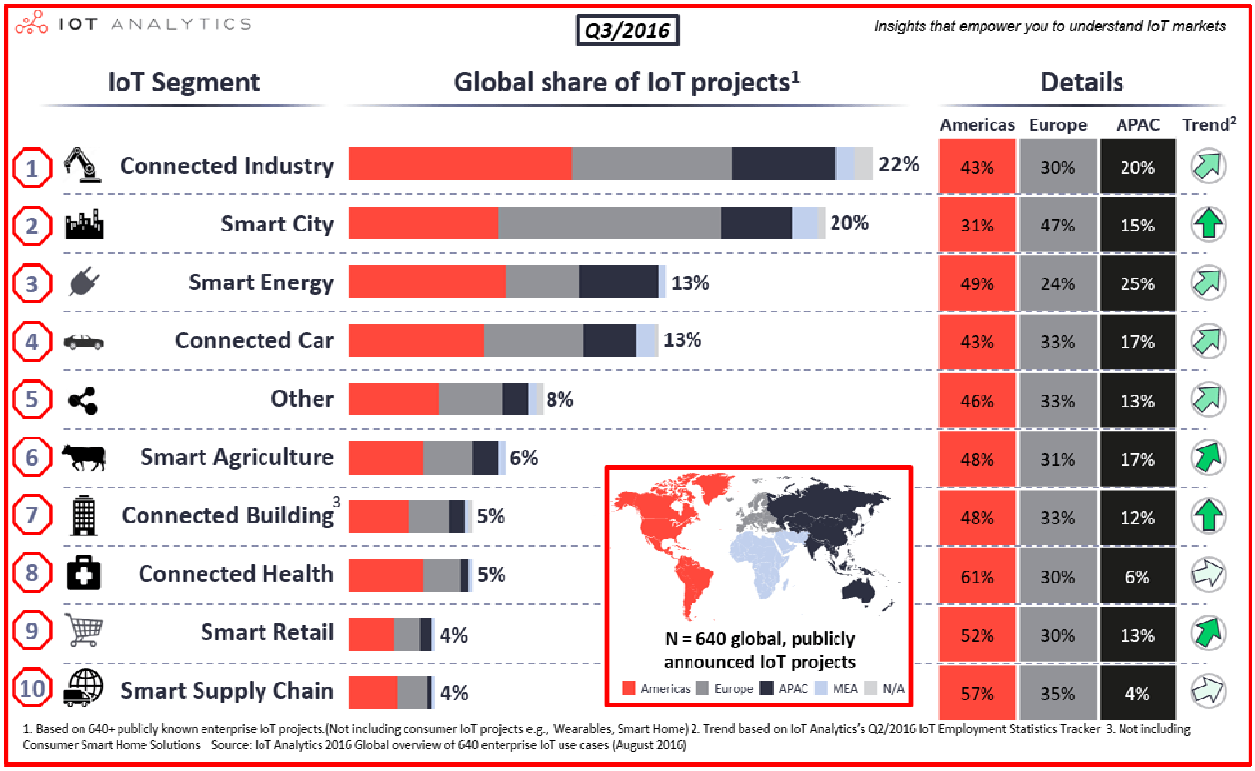


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Figure 2 – The top 10 IoT application areas

In fact, IoT applications in this industry are predicted to increase GDP by as much as 0.8percent, or $816 billion, over the next decade. That's why 62% of oil and gas CEO' priorities include digitalization.

The Internet of Things (IoT) in the oil & gas industry is the network of physical objects connected to the Internet. Wearable devices, vehicles, equipment, buildings, and just about any other thing can be embedded with electronics, software, sensors, and network connectivity. The ability to transfer data without requiring human interaction enables previously unprecedented amounts of data to be collected and exchanged with other devices, or through a central platform. Increasingly, forward-thinking oil & gas organizations are focusing their IoT initiatives less on underlying sensors, devices, and "smart" things and more on developing bold approaches for managing data, leveraging "brownfield" IoT infrastructure, and developing new business models.

Benefits of IoT in Oil&Gas sector are better field communication, reduced costs of maintenance, real-time monitoring, digital oil field infrastructure, reduced power consumption, mine automation, greater safety and security of assets, and thus higher productivity.

IoT will improve energy efficiency, remote monitoring and control of physical assets, and productivity through applications as diverse as home security to condition monitoring on the factory floor.

Benefits of IoT in Operational Excellence:
– Predictive maintenance.
– Pipeline and equipment monitoring.
– Location Intelligence.
– Emissions monitoring and control and release management.

Predictive maintenance is performed based on the current condition of a piece of equipment. For example, if a coil is running too hot, its failure is imminent and requires a technician to diagnose the cause. Predictive maintenance allows O&G companies to leverage the remote monitoring of equipment through sensors to make important decisions about whether or not something needs to be shut down, fixed, replaced, etc. Sensors that collect data send companies an alert when machines need to be maintained, preventing expensive equipment failure, wasted money, and manpower.

The upstream service (geological discovery and drilling) is area of high risks. IoT helps to prevent the major risks because they based on near-real-time data. That fact decrease non-productive time (NPT) and increase a company profit.

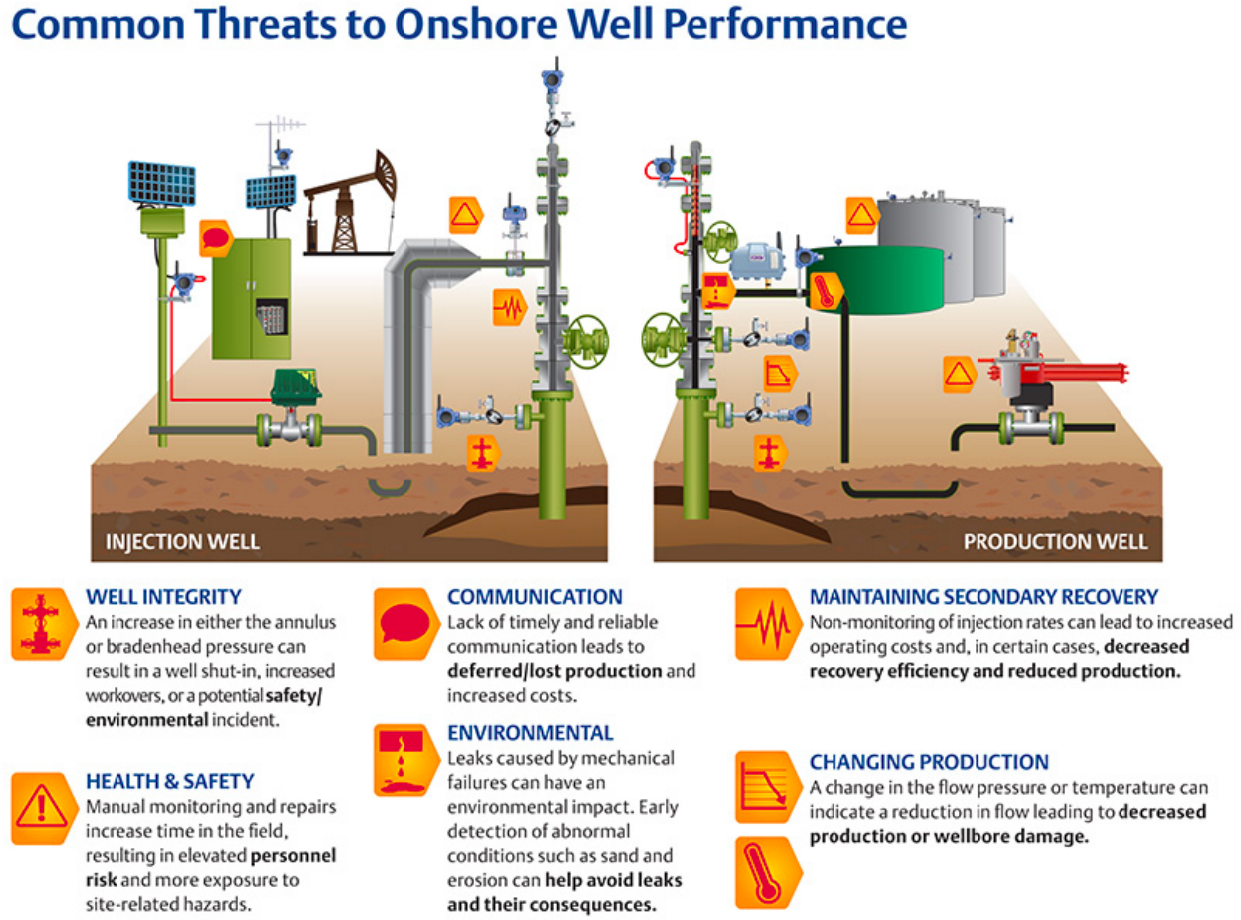

Figure 3 – Main Problems in oil and gas sector

The majority of O&G facilities need to be monitored on a regular basis. This is possible through remote services that allow facilities to react to problems through predictive maintenance. With tank levels' pressure and flow rates monitored daily along with various other controls, these machines are not exempt from wear and tear and often need regular service.

Benefits of IoT in Operations:
– Real-time machine and sensor integration.
– Real-time alerts.
– Link to enterprise resource planning data to trigger maintenance workflow.

– Plant dashboards and trend analysis.
– Asset information network.
– Fleet operations monitoring.

With the O&G industry under constant pressure to improve safety and operational results and to produce significant returns, asset tracking, and equipment monitoring have become the fastest growing wireless sensor network oil and gas IoT applications. Due to oil's dramatic price volatility, companies are spending more time analyzing their investments and internal operations to see where reductions or changes can take place while still maintaining the business and maximizing asset utilization.

Asset management is one of the core areas in the industry that can significantly influence operational performance. Operation productivity can be improved by optimizing production and making production more predictable through enterprise asset management (EAM).

With asset tracking, assets are integrated into one unit to enable companies to digitally transform their operations and monitor multiple wells or sites simultaneously. For instance, a single pump failure can cost a company as much as $300,000 and a lost day of production.

IoT sensors can monitor key pipeline equipment more accurately and cheaply. It can allow companies to survey potential drilling sites and point out the exact location for a pump and filter replacement refining the process and provide greater insight. Additionally, the use of sensors permits oil companies to monitor a large number of processes along with inventory and oil and gas shipments.

According to PWC Company digital transformation will include the following trends:
– Touch devices.
– Integrated Center of Operating Control (ICOC).
– Drones for observation.
– Request for rendering oilfield service services (NSU) in real time.
– Analysis of data in real time.
– Intelligent devices.
– 3D-printers and drones for delivery.

By means of touch devices on drilling rigs, wells and installations of a system of collecting and preparation it is planned to carry out detection of the abnormal temperature changes, pressure and an expense.

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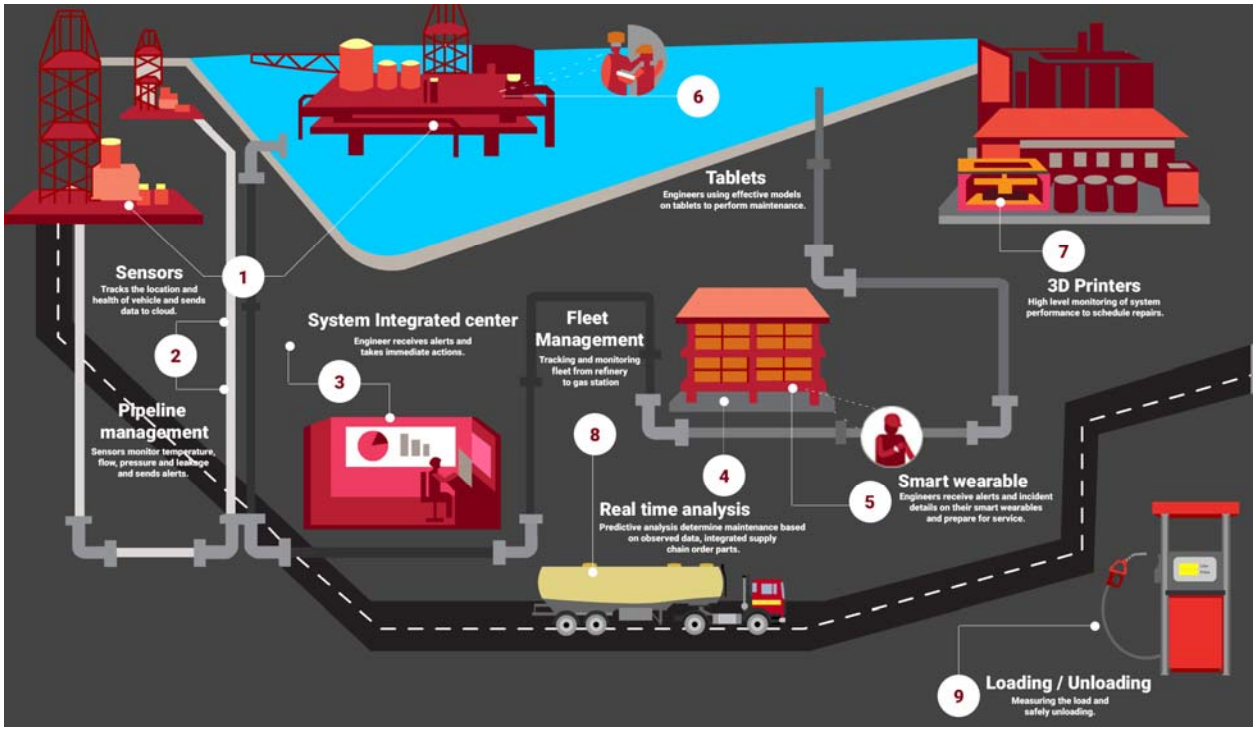

Figure 4 – Fixation of Problems by Smart Technologies

The specialist of the center of the integrated operations (CIO) in the critical situation will receive warning sign and begins to conduct diagnostic testing by an interactive or virtual three-dimensional model. The air drones examine the offshore drilling rig, the external systems of collecting, preparation and transport of products and in real time transfer pictures and video records to CIO. CIO engineers define the need for concrete services and create an inquiry for suppliers of oil and gas services. The most welcome offer is accepted in real time. So the company can order necessary equipment as a result of monitoring. The workers and engineers obtain warning signs and information in case of trouble on mobile devices. That will help to prepare in real time replacement of broken detail by 3D printer. The oil gas sector employees usually need a particular time to reach a place of destination. With the digital mobile operator, they will have direct access to the recommendations of experts, online to information and an opportunity to print on the 3D-printer small details in place.

Global Reach

IoT is removing the physical barriers so O&G companies helping reach broader target audiences and opening up new global business opportunities.

O&G sites aren't typically found next to your local grocery store. The majority can be found in dangerous and remote locations that are not conducive to the health and safety of neither workers nor the planet. Reservoirs can be submerged to depths of up to 3,000 meters offshore and rigs may be far offshore, sitting near faultiness where dangerous circumstances could happen at any time.

Discussion. Smart oil and gas complex should be oriented (table 1) on a significant increase in labor productivity, a significant reduction in labor and material resources, a decrease in capital and operating costs, leveling of anthropogenic impact on the environment.

Table 1 – The advantages of using digital technology

Indicators	Traditional	Digital	Smart
Growth of upstream service, %	1.0	4.0	10.0
Increase in oil reserves, billion tons	5.0	10.0	15.0
The cost for automation, %	0.5-1.0 or 0.75	1.0-2.0 or 1.4	2.0-4.0 or 3.0
Reducing cost of upstream service	2.0	5.0	15.0
The growth of Labor productivity, %	1.0	5.0	10.0

The most important task that the oil business wants to decide with using digital technology - this increases the degree of extract 's oil resources: they provide an opportunity not only to concentrate huge amounts of data on the state of oil fields but also to use them in complex decision-making models for optimizing oil recovery for each particular borewell. To do this, the main production structures (including platforms, wells, pumps, pipelines, compressors and etc.) combine with using telecommunications at single system what allows in a quasi-continuous mode to monitor all technological processes of exploration and production.

The list of breakthrough digital innovative technologies of oil and gas production:

1. Field of intelligence in development time - passive borewell monitoring.
2. Field of drilling - drilling systems without the Badger Explorer drilling rig.
3. Field of development - smart flooding, fiber-optic development monitoring systems, giggling modeling.
4. Field of production - smart borewell, bionic borewell.
5. Field of environmental protection - real-time environmental monitoring .

According to experts, the latest digital technologies are most important for the oil industry, based on which they are possible:

– Remote telemetry. Smart digital sensors located at significant distances from control points allow seismic exploration of productive horizons and gravity surveys, electromagnetic monitoring, and measuring surface geophones and geophones in wells. The small increase in the accuracy of seismic prospecting methods in the productive horizons of an oil field will increase the recovery of residual oil reserves by 3–7 %.

– Visualization. 3D format interpretation of large and complex arrays of data helps groups planning development of oil fields to optimize the location of the and well directed but also minimize errors in time and depth of penetration, accelerates the rate of production and reduces costs.

– Rational sinking and its completion. Real-time drilling data from the deep seabed helps engineers avoid many technological mistakes. So, sensors of low temperatures, pressure, and other parameters allow you to optimize the productivity of new horizons, reduce the negative impact of various impurities, identify water breakthrough zones, etc.

– Automation. The widely used technologies of remote monitoring and control make it possible to automate data collection, as well as reduce the number of production personnel. Modern technologies to optimize production and forecasting significantly improve the characteristics of production processes and help prevent potential accidents.

– Data integration. Combining collection systems and data management about productive horizons, well condition and the entire technology allows exploration and mining organizations to make effective decisions. It opens up the possibility to further analyze the current situation, develop an optimal management strategy and reduce the fixed costs.

The organization of the management of oil production from remote centers through electronics means not only improving mining technology or increased use of digital technology but also changing the right direction in which the processes of oil production have so far developed.

Conclusion. Technology is disrupting the status quo in the oil and gas industry. AI and robotic solutions can help us create models that will predict behavior or outcomes more accurately, like improving rig safety, dispatching crews faster, and identifying systems failures even before they arise. As a result of the implementation of the Digital Kazakhstan program, taking into account the above approaches, the following planned indicators can be achieved by 2021:

– the number of Internet users - 81 %;

– the level of digital literacy of the population - 81.5%;

– labor productivity growth in ICT - 5.9 %;

The oil & gas industry is on way to understand the potential of digitalization (IoT and AI). The collaborative usage of predictive and edge analytics for various processes in the industry can lead to safer and efficient operations. It's well known fact that information controls business. Most of potential investors see as main risk of O&G in cybersecurity.

A secure browser platform has intrinsic functionalities in terms of knowledge collaboration once connected to big data database. The collaboration is at multiple level, internally and externally. Internally by creating a workspace shared by a team and linked to the main database through publish/synchronize action, the ability for every user to share the same workflows and results. A services companies has a strong interest in developing plugins that his clients will use, because the client will be able to make a full use of the data taken in the wellbore. On the other side, an oil company will have access to a larger number of workflows, and thus a larger number of services companies to choose from for a logging work.

In the same way, a tool manufacturer interest is having client hearing about the full potential of a tool, and what better way than promoting it through the full capability of the tool measurements. A consultant strength results in the data processing to get the maximum knowledge out of information from measurements taken on wellbore. Another aspect of the collaboration is the ability to interact faster with the academic work, accelerating the spread of new techniques and measurements.

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ҚАЗАҚСТАНДАҒЫ МҰНАЙ-ГАЗ СЕКТОРЫН ЦИФРЛАНДЫРУ: БАСЫМДЫҚТАР МЕН ПРОБЛЕМАЛАР

Аннотация. Қазіргі әлемдегі сандық технологиялардың үлкен рөлі. Сандық технологиялардың негізгі артықшылықтары: халықты және бизнесті әлеуметтік қызмет көрсетуге оңайтылған қол жеткізу,тарту, жедел

алмасу бизнес үшін жаңа мүмкіндіктердің пайда болуы, жаңа сандық технологиялар мен өнімдер. Мемлекеттік бағдарламаның басымдығы "Цифрлық Қазақстан" ұлттық экономикалық өсу, бәсекеге қабілеттілік үшін сандық экожүйелер және халықтың өмір сүру сапасын жақсарту болып табылады.Сандық трансформация мұнай-газ секторының өндірістік шығындары мен санын азайтады және геологиялық барлау жұмыстарының тиімділігін арттырады, өндірістік жобаларға күрделі салымдар салады.Технологиялар көмегімен "Зияткерлік кен орны" кен орнында құрауы мүмкін шамамен 3%, қалпына келтіру жұмыстары пайдалану режимі 15-20%-ға қысқарады. Жабдықтар жөндеу санын жылына 20-дан 15-ке дейін қысқартуға мүмкіндік береді. Ақылды технологияларды енгізу артықшылықтармен қатар бірқатар маңызды проблемалар бар, олардың бірі қайта мамандандыру қажеттілігі болып табылатын түсіну қажет.

Түйін сөздер: сандық экономика, сандық түрлендіру, Еуразиялық экономикалық одақ, мұнай-газ саласы, интернет заттар, Жасанды интеллект.

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ЦИФРОВИЗАЦИЯ НЕФТЕГАЗОВОГО СЕКТОРА В КАЗАХСТАНЕ: ПРИОРИТЕТЫ И ПРОБЛЕМЫ

Аннотация. В современном мире цифровые технологии играют огромную роль. Основные преимущества цифровых технологий: упрощённый доступ населения и бизнеса к социальным услугам, ускоренный обмен информацией, появление новых возможностей для бизнеса, создания новых цифровых технологий, продуктов. Приоритетом государственной программы "Цифровой Казахстан" является прогрессивное развитие национальной цифровой экосистемы для экономического роста, конкурентоспособности экономики и улучшения качества жизни населения. Цифровая трансформация нефтегазового сектора уменьшит производственные затраты и число несчастных случаев, и увеличит эффективность геологоразведочных работ, капиталовложений в производственные проекты. С помощью технологий «Интеллектуальное месторождение» дополнительная добыча на месторождении может составить около 3%, время восстановления работы скважины сократится на 15-20%, щадящий режим эксплуатации подземного оборудования позволит сократить количество ремонтов с 20 до 15 в год. Необходимо понимать, что внедрение так называемых умных технологий имеет наряду с преимуществами ряд существенных проблем, одной из которых является необходимость переквалификации персонала. Одним из основных факторов риска является так же проблема кибер безопасности.

Ключевые слова: цифровая экономика, цифровое преобразование, Евразийский экономический союз, нефтегазовая отрасль, Интернет Вещей, Искусственный интеллект.

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REFERENCES

[1] The main directions of implementation of the digital agenda of EEU till 2025 are approved at a meeting of Council. 12.10.2017. Access mode: http://d-russia.ru/osnovnye-napravleniya-realizatsii-tsifrovoj-povestki-eaes-do-2025-goda-utverzhdeny-na-zasedanii-soveta.html – [Date of the address: 25.11.2017].

[2] Minasyan K. Calls of digital transformation demand consolidation of efforts of the countries of EEU. On March 15, 2017. http://egov.ifmo.ru/news_egov/news_17_03_15-1 [Date of the address 21.03.2019].

[3] What spoke at a forum of EEU "The digital agenda during a globalization era" about. 06.02.2018. http://d-russia.ru/o-chem-govorili-na-forume-eaes-tsifrovaya-povestka-dnya-v-epohu-globalizatsii.html — [Date of the address 21.03.2019].

[4] Prime ministers of the countries of EEU discussed formats and mechanisms of interaction in the digital sphere.- 02.02.2018. - http://www.eurasiancommission.org/ru/nae/news/Pages/2–02–2018–3.aspx [Date of the address 21.03.2019].

[5] Sargsyan T. Forming digital space: about results of work of ECE for 2017. 06.06.2018. http://d-russia.ru/formiruya-tsifrovoe-prostranstvo-o-rezultatah-raboty-eek-za-2017-god.html — [Date of the address 21.03.2019].

[6] Digital agenda of the Republic of Kazakhstan.-07.06.2018. http://d-russia.ru/tsifrovaya-povestka-respubliki-kazahstan.html [Date of the address 21.03.2019].

[7] Flichy P., Baudoin C. (2018, September 24). The Industrial IoT in Oil & Gas: Use Cases. Society of Petroleum Engineers. doi:10.2118/191756-MS

[8] Betelin V.B. "Digital field" – the way to hard to recover hydrocarbon reserves // Innovations. 2014. N 1(183). P. 37-38. Electronic resource. Access Mode: // cybe rleninka.ru

[9] Vorobiev A.E., Abishev A.A. Smart wells technology // Bulletin AIG (Kazakhstan). 2016. N 3(39). P. 3-11.

[10] Vorobiev A.E. Model of the "ideal" field on based 3D-software / A.E. Vorobiev, R. Ibragimov, S. Tralbessi // Bulletin of AING (Kazakhstan). 2016. N 3(39). P. 89-94.

[11] Dmitrievsky A.N., Eremin N.A. Modern scientific and technological revolution and the development of a paradigm shift carbohydrate of - natural resources // Problems of Economics and managing – Niya oil and gas sector. 2016. N 2(24). P. 13-19.

[12] World oil and natural gas markets: toughening competition / About TV. ed. S.V. Zhukov. M.: IMEMO RAS, 2017. 192 p.

[13] Dmitrievsky A.N., Martynov V.G., Abukova L.A., Eremin N.A. Digitalization and intellectualization of oil and gas fields // Modern Methods and Algorithms of Automation Systems (SA) In Oil and Gas Complex. 2016. N 2. P. 13-19.

[14] Dmitrievsky A.N., Eremin N.A. Smart Oil Technology and gas industry // 9th International Energy Week, December 2014. 49 p. Electronic resource – Access mode: //docplayer.ru/

[15] Kochnev A.A. The concept of "Intellectual" field // Master'S Journal. 2015. N 2. P. 165-171.

[16] Kushzhanov N., Almurzayeva B., Shunkeeva O., Seitenova S., Summers D., Summers B. The digital transformation of an education system. The virtual reality as new educational space // Bulletin of National academy of sciences of the Republic of Kazakhstan. ISSN 1991-3494. 2018. Vol. 3, N 373. P. 152-158. https://doi.org/10.32014/2018.2518-1467

[17] Kushzhanov N.V., Balginova K.M., Maydangalieva Z.A., Satygalieva G.B., Mahammadli D. The digital Kazakhstan.The developmemt of human resourses in education // Bulletin of National academy of sciences of the Republic of Kazakhstan. ISSN 1991-3494. 2018. Vol. 6, N 376. P. 82-94. https://doi.org/10.32014/2018.2518-1467.31

[18] Safarov R., Kushzhanov N. Methods for improving the socio-economic efficiency of state regulation of insurance activities in the digital economy // Bulletin of National academy of sciences of the Republic of Kazakhstan. ISSN 1991-3494.2018. Vol. 3, N 373. P. 130-136. https://doi.org/10.32014/2018.2518-1467

[19] Kushzhanov N.V., Maydangalieva Z.A., Almurzayeva B.K., Summers D.G., Utemissova G.U. Digital dementia. Cyberbullying and digital addiction // News of the National academy of sciences of the Republic of Kazakhstan. ISSN 2224-5294. 2019. Vol. 1, N 323. P. 5-15. https://doi.org/10.32014/2019.2224-5294.1

[20] https://iot-analytics.com/top-10-iot-project-application-areas-q3-2016/

[21] https://www2.deloitte.com/us/en/pages/consulting/articles/iot-digital-oil-and-gas.html

[22] https://blog.particle.io/2018/11/15/oil-and-gas/

[23] https://www2.deloitte.com/insights/us/en/industry/oil-and-gas/digital-transformation-upstream-oil-and-gas.html

[24] http://www.petrocouncil.kz/?page=view-news&id=70

[25] https://theiotmagazine.com/blockchain-iot-for-oil-and-gas-dx-bbcf8fb421f1

[26] https://emerj.com/ai-sector-overviews/ai-exploration-production-upstream-oil-gas-industry-current-applications/

[27] Kassymova G.K., Arpentieva M.R., Kosherbayeva A.N., Triyono M.B., Sangilbayev S.O., Kenzhaliyev B.K. (2019). Science, education & cognitive competence based on e-learning // Bulletin of the National academy of sciences of the Republic of Kazakhstan. 2019. Vol. 1, N 377. P. 269-278. https://doi.org/10.32014/2019.2518-1467.31

[28] Nikitina M.A., Chernukha I.M., Nurmukhanbetova D. E. Principal approaches to design and optimization of a diet for targeted consumer groups // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. ISSN 2224-5278. 2019. Vol. 1, N 433. P. 231-241. https://doi.org/10.32014/2019.2518-170X.28

[29] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[30] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[31] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[32] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[33] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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PREDICTION OF THE WELL PERFOMANCE INDICATORS WITH THE USE OF FUZZY CLUSTER ANALYSISYS

Abstract. The article is devoted to the results of information analysis and the establishment of the relationship between factors affecting operating efficiency and performance indicators (turnaround time, pump delivery rate) using a fuzzy clustering algorithm. One of the main tasks of the oil field practice is to assess the influence of various factors on the performance of field operations and to make the right technological decisions. The reliability of the estimates and decisions made is determined by how reliably the input and output variables and their values are selected. Often there are situations when, in the presence of the same data, fundamentally different results are obtained. To find specific expressions of these dependencies and parameters characterizing them, in particular, methods of statistical data processing are used. As a result of analyzing the causes of failures of subsurface pumps, factors that influence the pump efficiency at the considered fields were found, which were subjected to a fuzzy cluster analysis, that allowed to get an idea of the influence of these factors on the performance indicators under uncertainty. A connection was obtained between the input and output variables, which can be expressed by the fuzzy rules IF-THEN.

Keywords: water cutting, liquid flow rate, turnaround time, membership function, fuzzy cluster analysis.

Introduction. One of the main tasks of the oil field practice is to assess the influence of various factors on the performance of field operations and to make the right technological decisions. The reliability of the estimates and decisions made is determined by how reliably the input and output variables and their values are selected. Often there are situations when, in the presence of the same data, fundamentally different results are obtained. To find specific expressions of these dependencies and parameters characterizing them, in particular, methods of statistical data processing are used and, ultimately, real experimental material or field observation results are replaced by obtained laws and some integral, that is, common for the entire dependence as a whole, assessment of the measure of correlation ratio. In accordance with the adopted technology, the found law in the form of equations of the relation between influencing factors and efficiency indicators is then transferred to the object under study. This path is often a source of erroneous conclusions, since in most cases the formulation of goals and constraints when making decisions to improve the efficiency of pumps and field operation in the presence of multi-factorality, multi-criteria are fuzzy, in a word, all this requires the use of an appropriate apparatus.

Review of recent studies. When drilling wells, we have to deal with various parameters inherent in the oil reservoir as a complex system. One of the hardest problems in this case is the classification and clustering of this amount of information, as well as the selection of the most important data. The theory of fuzzy sets is successfully used to solve this problem in the development of fields and in decision-making.

In [1], fuzzy information about hydrocarbon deposits is considered as a situation that arose due to physical and linguistic uncertainty. Physical uncertainty arises due to the impossibility of determining the necessary physicochemical, mechanical, geological and technological parameters at each point of complex systems. As the author notes, information about the geological and technical system is limited and does

not fully cover the entire system. In addition, the measurement error and its subsequent interpretation contribute to the physical uncertainty of the quantitative estimates. The linguistic uncertainty of the qualitative parameters is due to the multiplicity and ambiguity of meanings and connections in the specialists' and experts' languages [1]. In the noted work it is considered that the quantitative and qualitative characteristics of a complex geological and technical system are fuzzy. In this regard, the author explores ways of operating a virtual field.

As noted in [2], a fuzzy situation can be of three types. In the fuzzy situation of the first type, alternatives from the set Ω are fuzzily described, that is, the properties of the alternatives can be assessed only at a qualitative level. The words "good", "bad", "fast", "slow", "many", "little" can be used as such assessments. The task of making a decision in this situation is to choose from the set Ω of an alternative that corresponds to some ideal more than any other alternative. To choose such an alternative, it is necessary to establish the degree of correspondence of each property of the analyzed alternatives to a similar property of an ideal. And then you should choose an alternative that has the best degree of compliance with the ideal. In a fuzzy situation of the second type, the conditions for determining the optimality principle are not clearly defined, that is, it is not clear with which of the known ideals alternatives should be compared. Such a situation arises when there can be several ideals, but the choice of one or another ideal depends on the conditions in which the decision is made. But these conditions themselves are fuzzy. In this case, the task of making a decision is to find out which of the possible situations is most likely. In the fuzzy situation of the third type, the optimality principle itself is not clearly defined, that is, the ideal with which alternatives should be compared is not exactly known, since this ideal is described only on a qualitative level. In this case, the task of making a decision is to determine what is preferable: "almost certainly corresponds to" or "is often considered."

Recently, in connection with an increase in computational power, modeling has been added to the standard decision analysis approach [3]. A risk analysis based on Monte Carlo simulation is a method by which risk and uncertainty, covering the main predictable variables in solving a problem, are described using probability distributions. Arbitrary sampling in distributions performed many, possibly thousands of times, allows you to create sequential scenarios.

Works on decision making under fuzzy conditions in the oilfield practice are shown in [4-10].

In [4], the separation of operational objects based on the theory of fuzzy sets is considered. It should be noted that the oil reservoir is not a clear and unambiguously determined object, and the applicability criteria are a logical generalization of expert assessments. At the first step, an approximate description of the parameters takes place with the help of linguistic variables (for example, a collector is estimated as "low-porous", "medium-porous" and "highly porous"). At the second step, based on expert knowledge, the function of belonging to a fuzzy set of "operational object" ("non-natural", "very bad", "bad", "mediocre", "good", "very good", "excellent") is constructed. At the third step, rules (R) for allocating an operational object (OO) are defined, for example: R1 = "IF the difference in the depth of reservoir formation is insignificant, THEN layers will represent a good OO", R2 = "IF geological factors (G) are good and technological factors (T) are good, THEN OO is good ", etc.

The advantages of applying the theory of fuzzy sets when solving problems of control and monitoring the processes of operating oil and gas fields under uncertainty are shown in [5]. The calculation algorithms are given, and the results obtained when working with fuzzy values are shown on real and hypothetical data. Fuzzy logic and its potential application in solving problems related to petroleum engineering are shown in [6–8]. The most successful application of intelligent systems, especially when solving technical problems, was achieved through the use of various intelligent tools individually and as a hybrid system. As shown in [11], expert systems are artificial intelligence tools that store and implement expert opinions, methods, and rules to achieve accurate system results. Fuzzy Petroleum Prediction (FPP) was developed to prepare an expert system using expert knowledge, analysis of oil well data, and redistribution of oil fields. The data required for its application were selected from various sources. The five factors used to predict oil were: temperature, pressure, density of crude oil, gravity, and gas density. FPP was applied at thirty wells in the Daqing oilfield as a published data set and other sources and achieved amazing results by developing various fuzzy functions.

As noted in [12], according to a survey conducted among oil and gas companies in Ghana, most managers use maximax, minimal losses and expected value when making decisions under conditions of

risk and uncertainty. But quantifying uncertainty is not an end in itself; eliminating or even reducing uncertainty is also not the goal. It is wrong to assume that uncertainty is reduced by simply modeling it, and making the right decisions simply requires more information [13]. Rather, the goal is to make the right decision, which in many cases requires an assessment of the corresponding uncertainties. The oil and gas industry has overlooked this goal for a long time, focusing efforts on giving decision-makers a deeper understanding of the possible outcomes that follow from important decisions [13]. In [14], the methods used to assess underground risk and volume uncertainty over the life cycle of exploration and production are considered. Although probabilistic methods are necessary for making decisions, it has been shown that they have limitations that should be understood. In borderline situations, they are difficult to justify, and non-technical factors are important when making decisions.

The advantages of taking into account the geological uncertainty when making decisions about the location of a well are estimated by comparing the results of decisions made using the theory of fuzzy sets with those made using the traditional approach using a single deterministic model [15]. In [16], fuzzy logic is used in problems of analytical modeling of enhanced oil recovery methods. Planning for the application of enhanced oil recovery methods (EORM) is a complex task that requires an integrated approach to its solution. Without optimizing the conditions for choosing technologies for implementation at a specific site, it is impossible to fully realize the capabilities of the EORM To overcome the problems arising from the use of strict limits of applicability of the methods, it is proposed to use fuzzy logic and assign reservoir objects to a class of fuzzy environments, and solving the problem of selecting the EORM - to making decisions in a fuzzy environment. Using the theory of fuzzy sets, one can quantify categorical concepts such as “very good” or “very bad”, which is especially important in tasks such as choosing an impact method, when the reservoir parameters differ in one direction or another from the applicability criteria.

In general, an analysis of accumulated research has shown the ability to solve a number of problems in an oil field, in particular, problems of modeling, decision-making, classification of objects, etc. using the theory of fuzzy sets.

Formulation of the problem. To assess the change of the pump operation parameters, it is proposed in the literature to use the delivery rate and the turnaround time.

The delivery rate and the turnaround time depend on many factors. In order to establish the influence of these factors, an analysis of information on the geological and technological characteristics of operating conditions has been carried out, which showed the impossibility of constructing statistical dependencies in this case due to its insufficiency. Recently, decision-making methods taking into account the conditions of uncertainty became widely used. One of such methods are methods of fuzzy classification.

The results of the analysis. As is known, the main problem in the operation of wells in complicated conditions is the deterioration of reliability indicators, which in turn affects the technical and economic indicators in general. The operation of pumps is influenced by numerous factors, both geological, and technical and technological.

Geological factors (gas, water, deposits of salt, paraffin, mechanical impurities, etc.) primarily characterize reservoir conditions.

Another group of factors is the factors associated with the design of a well or pump (diameters of production strings, hole curvature, pump components and parts, etc.). Naturally, all factors can be divided into factors with positive and negative effects on pump performance. To date, accumulated a large number of studies on the work of deep-well pumps in complicated conditions. As practice shows, a dry period of well operation takes up a small part of the total period and, therefore, the effect of water on the pump operation begins almost from the beginning of the well operation. The appearance of formation water in the oil is one of the main reasons worsening the performance of wells.

The appearance of formation water in oil leads to a number of complications during operation.

The operation of the pump is also affected by oil. Since it consists of active emulsifiers - asphaltenes, as well as resins, oil is prone to the formation of emulsions, which is also facilitated by clay and sand falling from the surface or from the formation. Since the viscosity and stability of the emulsion depend on the dispersion of the oil-water mixtures, and the subsurface pumps are one of the best dispersants, an emulsion is formed during the passage of fluid through the pump's working parts, the viscosity of which can increase tenfold compared to pure oil. The influence of all these factors is ambiguous, and therefore its

establishment by statistical means is difficult, often impossible. In such cases, the application of the provisions of the theory of fuzzy sets allows you to establish the desired relationship.

To establish the relationship between the performance indicators of the pump and the relevant factors characterizing the operating conditions of the wells, we have classified the operating conditions according to several criteria using a fuzzy cluster analysis program, described in [17, 18]. Water cutting, fluid flow rate, mechanical impurity level and productivity factor (input variables) for Karazhanbas deposit were selected as signs for which clustering was carried out, the turnaround time and deluivery rate were taken as output variables [19].

Currently, the tasks of cluster analysis, or automatic classification, are widely used in various fields, including the oilfield business, wherever there are sets of objects of arbitrary nature. In recent years, these methods became widely used in information analysis tasks. Traditional methods of cluster analysis suggest a clear division of the original set into subsets, where each point after splitting falling into only one cluster. However, as is known, such a restriction is not always true. Often it is necessary to produce a partition to determine the degree of belonging of each object to each set. In this case, it is advisable to use fuzzy methods of cluster analysis. The tasks in this formulation attract the interest of specialists involved in oil field practice [20]. One of the most important results in studying the operation of pumps during field exploitation is the determination of the delivery rate and the turnaround time.

As a result of the program implementation, homogeneous groups of data - clusters are obtained, the results of the noted clustering are shown in table. From this table, the mutual correspondence of the input and output variables is seen.

Mutual correspondence between the input (water cutting, fluid flow rate, productivity factor, mechanical impurity level) and output (turnaround time, delivery rate) variables

Water cutting	Fluid flow rate, tn/day	Productivity factor, tn/day*MPA	Mechanical impurity level, %	Turnaround time, days	Delivery rate
low	low	low	high	low	low
			low	medium	medium
high	medium	low	low	high	high
	high	high	high	high	high
		low	medium	high	high

Conclusion. The performed cluster analysis allows to give a qualitative assessment of the influence of marked factors on the pump efficiency indicators. For example, according to the data in Table 1, if the water cutting, flow rate and productivity factor are low, the mechanical impurity level is high, then the turnaround time and delivery rate will be low. Thus, the results of the analysis allow us to formulate fuzzy rules on the principle "if ... then ...", namely:

IF the water cutting is low and the fluid flow rate is low and the productivity factor is low and the mechanical impurity level is high, THEN the turnaround time is low and the delivery rate is low.

IF the water cutting is low and the fluid flow rate is low and the productivity factor is low and the mechanical impurity level is low, THEN the turnaround time is medium and the delivery rate is medium.

IF the water cutting is high and the fluid flow rate is medium and the productivity factor is low and the mechanical impurity level is low, THEN the turnaround time is high and the delivery rate is high.

IF the water cutting is high and the fluid flow rate is medium and the productivity factor is high and the mechanical impurity level is high, THEN the turnaround time is high and the delivery rate is high.

IF the water cutting is high and the fluid flow rate is high and the productivity factor is low and the mechanical impurity level is medium, THEN the turnaround time is high and the delivery rate is high.

As a result of analyzing the causes of failures of subsurface pumps, factors that influence the pump efficiency at the considered fields have been established, which have been subjected to a fuzzy cluster analysis, that allowed to get an idea of the influence of these factors on the performance indicators under uncertainty conditions.

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АНЫҚ ЕМЕС КЛАСТЕР-ТАЛДАУДЫ ҚОЛДАНА ОТЫРЫП, ҰҢҒЫЛАРДЫ ПАЙДАЛАНУ ТИІМДІЛІГІНІҢ КӨРСЕТКІШТЕРІН БОЛЖАУ

Аннотация. Мақала анық емес кластер-талдау алгоритмін қолдана отырып ақпаратты талдау нәтижелеріне және пайдалану тиімділігі мен тиімділік көрсеткіштеріне әсер ететін факторлар арасындағы өзара байланыс орнатуға арналған (жөндеу аралық мерзім, сораптың беру коэффициенті). Мұнай кәсіпшілігі практикасының басты міндеттерінің бірі кен орындарды пайдалану тиімділігінің көрсеткіштеріне әр түрлі факторлардың әсерін бағалау және дұрыс технологиялық шешімдер қабылдау болып табылады. Бағалау мен қабылданған шешімдердің дұрыстығы кіріс және шығыс айнымалыларының қаншалықты дұрыс таңдалуымен, олардың мәндерімен анықталады. Бір деректер болған жағдайда, нәтижесінде әртүрлі нәтижелер алынған жағдайлар жиі туындайды. Осы тәуелділіктер мен оларды сипаттайтын параметрлердің нақты өрнектерін табу үшін, атап айтқанда, деректерді статистикалық өңдеу тәсілдері пайдаланылады. Тереңдік сораптардың істен шығу себептерін талдау нәтижесінде қарастырылып отырған кен орындарында сораптардың тиімділігіне әсер ететін факторлар анықталды, оларға жасалған анық емес кластер-талдау аталған факторлардың белгісіздік жағдайда тиімділік көрсеткіштеріне әсері туралы түсінік алуға мүмкіндік берді. Анық емес ЕГЕР – ОНДА ережелерімен көрсетілуі мүмкін кіріс және шығыс айнымалылары арасындағы байланыс алынды.

Түйін сөздер: сулану, сұйықтық шығыны, жөндеуаралық мерзім, тиістілік функциясы, анық емес кластер-талдау.

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ПРОГНОЗИРОВАНИЕ ПОКАЗАТЕЛЕЙ ЭФФЕКТИВНОСТИ ЭКСПЛУАТАЦИИ СКВАЖИН С ПРИМЕНЕНИЕМ НЕЧЕТКОГО КЛАСТЕР-АНАЛИЗА

Аннотация. Статья посвящена результатам анализа информации и установлению взаимосвязи между факторами, влияющими на эффективность эксплуатации и показателей эффективности (межремонтный период, коэффициент подачи насоса) с использованием алгоритма нечеткой кластеризации. Одной из главных задач нефтепромысловой практики является оценка влияния различных факторов на показатели эффективности эксплуатации месторождений и принятие правильных технологических решений. Достоверность оценок и принятых решений определяется тем, насколько достоверно выбраны входные и выходные переменные, их значения. Часто возникают ситуации, когда при наличии одних и тех же данных, в итоге получаются принципиально различные результаты. Для нахождения конкретных выражений этих зависимостей и параметров, характеризующих их, используются, в частности, приемы статистической обработки данных. В результате анализа причин отказов глубинных насосов были установлены факторы, оказывающие влияние на эффективность насоса на рассматриваемых месторождениях, которые были подвергнуты нечеткому кластер-анализу, позволившему получить представление о влиянии отмеченных факторов на показатели эффективности в условиях неопределенности. Была получена связь между входными и выходными переменными, которые могут быть выражены нечеткими правилами ЕСЛИ-ТО.

Ключевые слова: обводненность, расход жидкости, межремонтный период, функция принадлежности, нечеткий кластер-анализ.

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REFERENCES

[1] Yeremin N.A. Modern oil and gas fields exploitation. Smart well. Intelligent oilfield. Virtual company. M.: "Nedra-business center", 2008. 244 p.

[2] Grekhov A.A. Theory of decision-making. Petrodvorets: Naval Institute of Radio Electronics, 2007. 445 p.

[3] Macmillan Fiona. Risk, Uncertainty and Investment Decision-Making in the Upstream Oil and Gas Industry. Ph.D. thesis. Aberdeen: University of Aberdeen, October 2000. 250 p.

[4] Mukhametzyanov I.Z. Methodical features of the application of the theory of fuzzy sets in the tasks of the oil and gas industry. Ufa: Ufa State Petroleum Technological University, 2017. 86 p.

[5] Altunin A.E., Semukhin M.V. Models and algorithms of decision-making in fuzzy conditions. Monograph. Tyumen: Publishing of Tyumen State University, 2002. 268 p.

[6] Mohaghegh S. Virtual intelligence and its applications in petroleum engineering // J. Pet. Technol. Distinguished Author Series, 2000.

[7] Zadeh L.A. Fuzzy Sets // Information and Control. 1965. Vol. 8. P. 338-353.

[8] Nikravesh Masoud, Dobie Chuck A., Patzek Tad W. Field-Wise Waterflood Management in Low Permeability, Fractured Oil Reservoirs: Neuro-Fuzzy Approach // SPE 37523, SPE International Thermal Operations & Heavy Oil Symposium held in Bakersfield. California, U.S.A., 10-12 February 1997.

[9] Yeremin N.A. Modeling of hydrocarbon deposits using fuzzy logic methods. M.: Nauka, 1994. 462 p.

[10] Mirzadzhanzade A.Kh., Khasanov MM, Bakhtizin R.N. Modeling of oil and gas production processes. Nonlinearity, disequilibrium, uncertainty. Moscow – Izhevsk: Institute for Computer Studies, 2004. 368 p.

[11] Ghallab S.A., Badr N., Salem A.B., Tolba M.F. A Fuzzy Expert System For Petroleum Prediction // WSEAS, Croatia. 2013. Vol. 2. P. 77-82.

[12] Boachie Christopher. Decision Making under Risk and Uncertainty in the Oil and Gas Industry. Tools and Techniques for Economic Decision Analysis, 2017. 27 p.

[13] Bickela J. Eric, Bratvoldb Reidar B. Decision-Making in the Oil and Gas Industry - From Blissful Ignorance to Uncertainty-Induced Confusion // SPE Annual Technical Conference and Exhibition, Anaheim, California, U.S.A., 11-14 November. Society of Petroleum Engineers, 2007. 15 p.

[14] Binns Paul, Corbett P.W.M. Risk and uncertainty from frontier to production – A review // First Break. 2012. Vol. 30(6). P. 57-64.

[15] Paulo Sergio da Cruz. Reservoir management decision-making in the presence of geological uncertainty. Ph.D. diss. Stanford University, March 2010. 221 p.

[16] Kononov Yu.M., Ivanov E.N. The use of fuzzy logic in the problems of analytical modeling of the methods of increasing oil recovery // XVIII International Scientific and Practical Conference "Modern Technique and Technologies", Section 9: Quality Control and Management. National Research Tomsk Polytechnical University, Russia, 9-13 April 2012. P. 95-96.

[17] Aliev R.A, Guirimov B.G. Type-2 Fuzzy Neural Networks and Their Applications. http://www.springer.com/us/book/9783319090719

[18] Demidova L.A., Konyaeva E.I. Clustering of objects using FCM-algorithm on the basis of type-2 fuzzy sets and genetic algorithm // Vestnik of RSREU. Ryazan. 2008. Vol. 4 (Issue 26).

[19] Karazhanova M.K., Piriverdiyev I.A. Analysis of the Impact of Operating Conditions of Pumps on their Efficiency Indicators Using Fuzzy Clustering Algorithm // 12th International Conference on Application of Fuzzy Systems and Soft Computing, ICAFS 2016. Vienna, Austria, 29-30 August 2016. P. 163-167.

[20] Efendiyev G., Mammadov P., Piriverdiyev I., Mammadov V. Estimation of the lost circulation rate using fuzzy clustering of geological objects by petrophysical properties // Visnyk Taras Shevchenko national university of Kyiv. Geology. 2018. Vol. 2(81). P. 28-33.

[21] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[22] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[23] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[34] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[35] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310

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MASTERING AND DEVELOPMENT HYDROPOWER IN KAZAKHSTAN

Abstract. The power characteristics of the constructed and operated hydroelectric power plants in Kazakhstan are given. It is shown that the share of electricity generated at hydropower plants in the total volume of electricity production in the country is still insignificant (8.4%, a), and the total installed capacity is only 2580 MW. Existing technological schemes of small hydropower plants require further improvements and new approaches in a constructive solution. It is indicated that the results of 80-85% of the research work performed are limited to the study of the parameters of prototypes or prototypes of improved and new HPP designs.

Existing promising domestic developments can serve as basic solutions for mastering them in production. It has been proposed to update the previously developed "Development Schemes for Small Hydroelectric Power Stations in Kazakhstan" on the basis of a feasibility study and an order of relations with local administrations for water use and land acquisition.

Key words: hydropower, hydroelectric power station, development, implementation, recommendations.

As you know, hydropower is the most common in practice and technologically mature industry in comparison with other known sources of renewable energy sources[1- 4]. This is due to the fact that during the construction and operation of a particularly small and mini hydroelectric station, the natural landscape is preserved, in many cases there is practically no stress on the ecosystem.

Hydroelectric power stations built in the hydropower system of Kazakhstan are mainly concentrated in the East Kazakhstan (East Kazakhstan), Almaty, Zhambyl and Turkestan regions of the republic [5, 6].

The East Kazakhstan region has the Shulbinsk Hydroelectric Power Station (702 Mw), the Ust-Kamenogorsk Hydroelectric Power Station (331 Mw), and the Leninogorsk cascade of hydroelectric power stations. MW), as well as a series of mini-hydropower plants: Aksu HPP-1 (1.9 Mw), Issyk HPP-2 and 3 (6.1 Mw), Karatal HPP-2, 3, 4 (11.9 Mw), Sarkand HPPs (0.5 Mw), Antonovskaya HPP-3 (1.6 Mw), Uspenovskaya HPP-4 (2.5 Mw), Intalinskaya HPP-5 (0.6 Mw). In the Zhambyl region there are Merke power stations-1, 2, 3 (3.6 Mw), Karakystakskaya HPP (2.1 Mw), Taso Keli HPP (9.2 Mw).

The installed capacity of the Shardara hydroelectric station, located in the Turkestan Oblast, is 100 Mw. It is currently being upgraded, according to the results of which the capacity should increase to 126 Mw.

At the same time, the Almaty region is considered one of the main producers of renewable energy sources from water resources, where by 2020 it is planned to develop 11 new projects, including a cascade of hydroelectric power plants with a total capacity of 42 Mw on the Koksu River and a single hydroelectric station with a capacity of 60.8 Mw on the Chilik River.

Since all hydropower plants of Kazakhstan have a relatively small capacity, their task is to regulate the load schedule, fulfilling the classic function of maneuverable power and "closing" consumption peaks. In such a configuration, the role of important elements of the power system, but not determining its development, remains behind the hydropower plants. Despite the fact that over the past 25-30 years, the total capacity of Kazakhstan's hydropower plants has grown, the overall level of electricity consumption

produced on their turbines, according to BP Energy Outlook, by the mid-2010s after decades of ups and downs returned to the values of the late 1980s.

However, the share of electricity generated at hydropower plants in the total volume of electricity production in the country is still insignificant (8.4%, a), and the total installed capacity is only 2580 Mw, while in Tajikistan it is equal to 5190 Mw (figure 1).

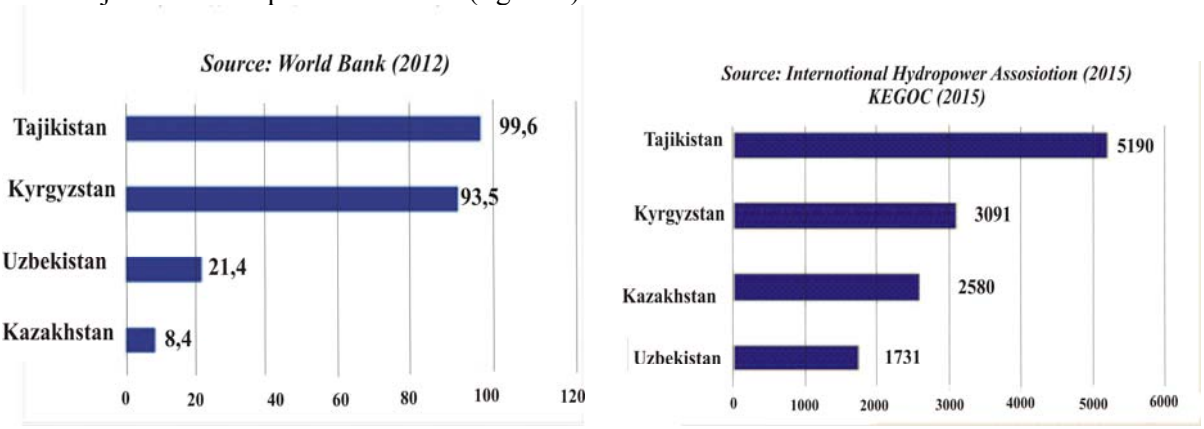

Figure 1 – The share of electricity generated at hydropower plants
in the total volume of electricity production in countries,% (a) and the total installed capacity, Mw (b)

As can be seen from these diagrams, these indicators are significantly inferior to the developed volume of energy of water resources of the countries of Central Asia [7].

The main problem in relations between the countries of Central Asia is the unbalanced system of water resources exploitation in the hydropower regime, during which winter floods are replaced by water shortages during the growing season of the main crops.

At present, Kazakhstan's hydropower potential is estimated at 170 billion kWh hours per year. According to experts, in the South it is possible to cover the shortage of electricity by building a cascade of environmentally friendly micro and mini hydropower plants, since the potential under consideration in this zone is estimated to be no less than 4 GW of power. Due to this, the share of development of available potential hydro resources in Kazakhstan, compared with the countries of Central Asia, increased slightly (figure 2, a) [8].

In 2017, the capacity of small hydropower plants in Kazakhstan increased by 30 MW due to the wide placement of numerous private power plants, such as Mankenskaya HPP (2.5 MW, 283 million tenge) in the Turkestan region (figure 2, b).

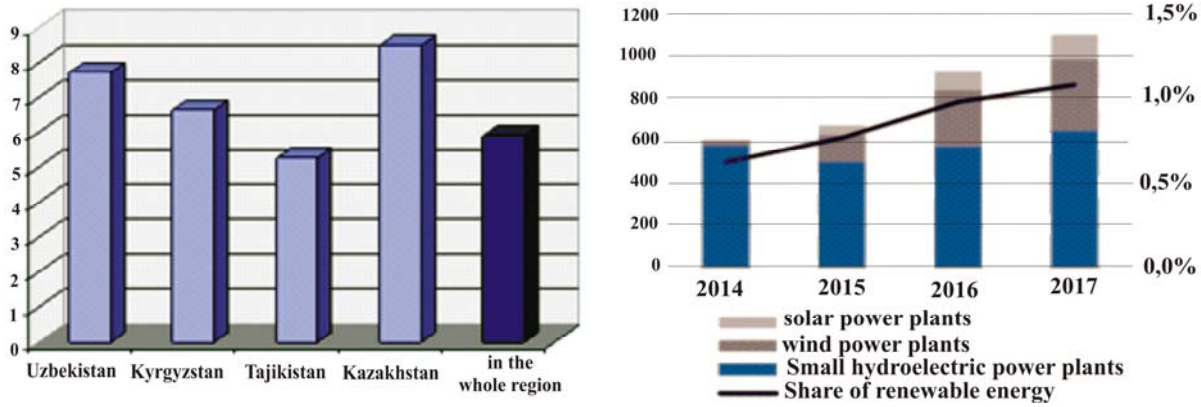

Figure 2 – Share of the use of potential hydro resources in the countries of Central Asia (a)
and production of electricity based on renewable energy sources in Kazakhstan

By 2020, Kazakhstan plans to build 41 small hydropower plants with a total capacity of 539 Mw, which will provide 17.6% of the total potential of renewable energy sources in Kazakhstan [9].

The feasibility of developing small hydropower industry in the republic is confirmed by the current trend in global hydro-construction experience. Due to the competitive price for electricity generated at small hydropower plants, they currently represent a very attractive business for investors.

The promising development of a small hydropower plant provides not only a reduction of the negative impact on nature, but also the full realization of positive factors, including integrated development of construction areas, regulation of weaving, creation of recreation areas, etc. from the mode of operation of the power system.

In this regard, in 2005, the Government of Kazakhstan developed and adopted a concept for the extensive construction of a small HPP with an annual electricity output of 4.8 billion kWh. The Law of the Republic of Kazakhstan “On Supporting the Use of Renewable Energy Sources” No. 165-IV of July 4, 2009 provides for the creation of favorable conditions for the construction and operation of facilities for the use of renewable energy sources.

The existing technological schemes of a small hydroelectric station with reference to the conditions of their use require further improvement and new approaches in a constructive solution[10-14].

In Kazakhstan, the development and design of hydropower plants began to be closely pursued in the 40s of the last century. This was facilitated by the demand for small hydropower in general and the creation of a branch of the All-Union design organization "Hydroproject" in Kazakhstan [6].

As a result, improved versions of the Almaty cascades of a small hydropower plant were developed and built, and successful work was continued on the efficient use of energy of water resources, especially South-East Kazakhstan.

Currently, more than 10 scientific organizations and educational institutions are involved in the development and research of small and mini hydropower plants. The leading ones are the Kazakh Research Institute of Energy, the KI Kazakh National Research Technical University. Satpayev, Institute of Energy and Communications, M.-H. Dulati Taraz State University, National Engineering Academy of the Republic of Kazakhstan.

The available groundwork on the subject matter of the research and technological areas is characterized as follows. Since 2010, on the basis of budget financing, 8 research projects have been carried out and innovative patents have been received for more than 40 inventions in the design of a hydroelectric power station, hydraulic units and for improving the methods of building and operating small hydropower plants. The results of 80-85% of the research work carried out are limited to studying the parameters of prototypes or prototypes of improved and new designs of hydroelectric power plants and hydraulic units in the laboratory.

Some designs have passed production tests. The derivational rotor mini hydroelectric station tested on the Turgen River (V.M. Nizovkin) with a rated power of 3 kW, with a head H = 20 m and a flow rate of 30 l / s with a pipeline length of 500 m showed the prospects of the chosen direction both in terms of costs and energy efficiency. It is focused on mountainous and foothill areas of the republic with river slopes of more than 50. According to the authors' calculated data, the development will reduce the cost of hydroelectric power plants from 350-700 US dollars / kW to 100-250 US dollars / kW at a cost price of 1 kW / h of electricity 0.05 - 0.4 US cents.

The following two developments with the name "Small diversion hydroelectric station" (№25130 RK, 2014, KazNRTU named after K.I. Satpayev) [15] and "Autonomous low-pressure mini-hydroelectric station with direct-flow turbine" (№13064 RK, 2003, KazNIIenergy) " [16] were studied under the program “Development of clean energy sources of the Republic of Kazakhstan for 2013-2017 within the framework of EXPO-2017” and their operating models were demonstrated at the exhibition EXPO-2017 and received positive feedback from experts from leading countries.

This first technical solution was also awarded the certificate and medal of the World Intellectual Property Organization (WIPO), as the best invention of 2012. The novelty lies in the improvement of the water supply unit of the existing small hydroelectric power plants using hydrocyclone grit catchers of intensive operation of a simplified design, which reduces the cost of building a water treatment unit from 30% (existing) to 7%.

A prototype of a hydrocyclone with a diameter of 700 mm was tested under production conditions and it showed the degree of water purification from mechanical impurities up to 96-98%. The installed capacity of one used hydro-cyclone hydroelectric station is 3-10 MW. The calculated annual electricity

generation reaches 4.0–5.0 million kWh.Due to the protection of the turbine against abrasive wear, its service life is significantly increased [17-19].

The advantage of the second development is to simplify the design and increase the reliability of operation of the unit operating as part of a small hydroelectric station. This is achieved due to the presence of a turbine, which is made of a cylindrical tube, inside which there are plates with the possibility of a smooth flow around it. The design feature of the blades of the water turbine contributes to the production of energy with a small flow of water, and also eliminates uneven rotation and vibration. There is no need for the construction of pressure structures.

In Kazakhstan, an invention was also developed with the name "Circulating mini-hydroelectric power station" [innovation patent KZ No. 29169.28.08.2013, TarGU after M.- H.Dulati] [20], characterized in that in the bottom of the cylindrical container there is an opening with a shell, in front of which is arranged a nano-scavenging galera, the output part of which passes under the bottom of the cylindrical container. At the same time, the supply of sediment in the annular sedimentation galarium is carried out tangentially.

However, in our opinion, the implementation of the water intake basin of the circulating action in the form of a cylinder to a certain extent reduces its separation capacity of sand from the incoming water and complicates the accumulation and removal of entrained mechanical impurities into the dump. The presence of a rectangular cross, on which the turbine is mounted, prevents rotation of the flow inside the cylindrical basin.

A new technical solution developed in the National Academy of Sciences of the Republic of Kazakhstan under the name "Hydroelectric power station of hydrocyclone type" (figure 3) increases the efficiency of the hydraulic unit, improves the power characteristics of the unit to 15-20% [21]. The degree of water purification in hydrocyclones when operating in pressure mode reaches 95-97%.

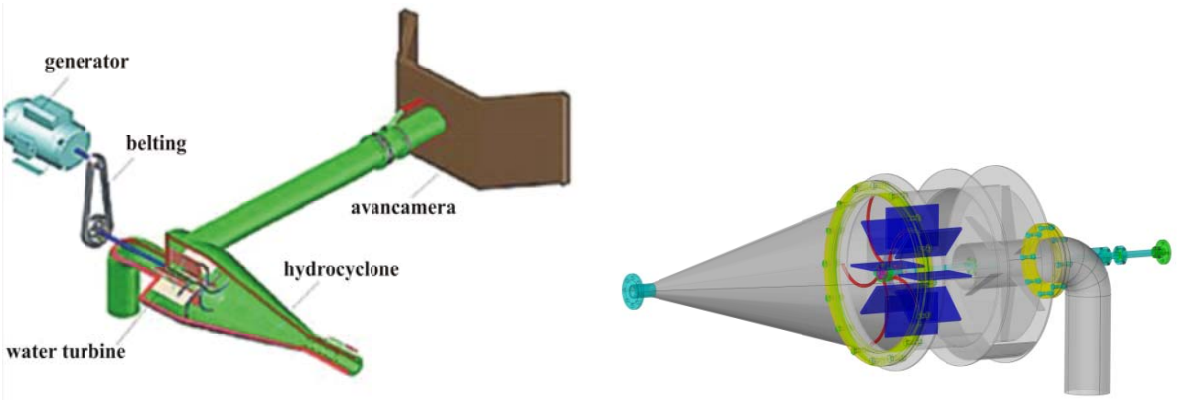

Figure 3 – General types of layout hydro hydroelectric mini hydroelectric type (a) and hydro turbines in a hydro cyclone body (b)

The simplicity of the design of the hydroelectric station and the technological layout design reduces manufacturing costs by up to 20%.

Here protection of the turbine against abrasive wear is achieved by the station's water intake being made in the form of a cylindro-conical hydrocyclone capsule, inside of which a lobed hydroturbine with a smaller diameter is located coaxially with a smaller diameter, the axis of the turbine is attached to the capsule by a discontinuous partition of curved plates spins of water tangentially supplied to the water intake.

This technical solution allows, in contrast to existing analogues, to use mini hydroelectric power plants in a capsule version and to master the hydrocyclone effect for separating the solid phase from the liquid when the water turbine is supplied.

The above improvement in power characteristics by 15-20% is achieved through the interaction of two surface swirling threads.

Conclusion. The generated capacity of hydroelectric power plants capable of covering peak loads is about 4% of the installed capacity of all hydroelectric power plants or about 5% of the capacity currently used. This proportion is not enough to cover peakloads.

Available promising domestic technical developments to a certain extent can serve as basic solutions for their development in the production. The introduction of such technological schemes, taking into account design features, will significantly increase the degree of development of economically justified hydropower resources in the Republic of Kazakhstan, which currently stands at 26 %.

This figure in economically developed countries ranges from 50-90% (in the US and Canada – 50-55 %, in Western Europe and Japan from 60 to 90 %).

It is necessary to update the previously developed "Scheme of development of small hydropower plants in Kazakhstan» on the basis of a feasibility study and the order of relations with local administrations on water use and land allotment. It is necessary to conduct a large-scale survey of existing and decommissioned small hydropower plants, develop recommendations to improve their performance and efficiency, reduce the cost of construction and operation. It is advisable to perform the optimization of the layout design of small hydropower plants considering the eco-geographical and economic factors.

The article is based on the results of the target program "Creation of the basis of serial production of renewable energy sources of Kazakhstan of world level" (BR05236263, NAS RK, 2018-2020).

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ҚАЗАҚСТАНДАҒЫ ГИДРОЭНЕРГЕТИКАНЫҢ ҚОЛДАНУ ЖАҒДАЙЫ ЖӘНЕ ДАМУЫ

Аннотация. Қазақстанда тұрғызылған және игеріліп жатқан гидроэлектростанциялардың қуаттық сипаттамалары келтірілген. Елімізде өндірілетін электр энергиясының жалпы көлеміне шаққандағы гидроэлектростанцияларда өндірілетін электр энергиясының үлесі бұрынғысынша төмен деңгейде (8,4%) және жалпы белгіленген қуаттылығы 2580 МВт-тен аспайтыны көрсетілген.

Пайдаланыстағы шағын гидроэлектростанциялардың қазіргі технологиялық сұлбалары жаңа жетілдірулерді қажет етеді. Ғылыми зерттеу жұмыстарының 80-85%-ы жақсартылған және жаңа ГЭС жобаларының тәжірибелік үлгілерінің параметрлерін анықтаумен ғана шектелген. Жаңадан жасалған перспективалық отандық техникалық шешімдер оларды өндірісте кең көлемде пайдалануға мүмкіндік бере алады. Бұрынғы Қазақстанда әзірленген «Шағын ГЭС-терді дамыту схемаларын» жаңартуды техникалық-экономикалық тиімділігін және суды пайдалану, құрылысқа жерді алу үшін жергілікті әкімшіліктермен өзара іс-қимыл тәртібінің негізінде қайта орындау ұсынылған.

Түйін сөздер: гидроэнергетика, гидроэлектростанциялар, дамыту, әзірлеу, енгізу, ұсыныстар.

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ОСВОЕНИЕ И РАЗВИТИЕ ГИДРОЭНЕРГЕТИКИ В КАЗАХСТАНЕ

Аннотация. Приведены мощностные характеристики построенных и эксплуатируемых гидроэлектростанции в Казахстане. Показана,что доля электроэнергии, вырабатываемой на ГЭС в общем объеме производства электроэнергии в стране еще незначительна (8,4%), а совокупность установленной мощности составляет всего 2580 Мвт. Существующие технологические схемы малой ГЭС требуют дальнейшего усовершенствования и новых подходов в конструктивном решении. Указаны,что результаты 80-85% выполненных научно-исследовательских работ ограничены изучением параметров макетных или опытных образцов усовершенствованных и новых конструкции ГЭС. Имеющиеся перспективные отечественные разработки могут служит базовыми решениями для освоения их на производстве. Предложено обновить ранее разработанные «Схемы развития малых ГЭС в Казахстане» на основе технико-экономического обоснования и порядка взаимоотношений с местными администрациями по водопользованию и отвода земель.

Ключевые слова: гидроэнергетика, гидроэлектростанции, развитие, разработка, внедрение, рекомендации.

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REFERENCES

[1] European Small Hydropower Association ESHA (2004). "Guide on How to Develop a Small Hydropower Plant" Brussels, Belgium (in Eng.).

[2] European Renewable Energy Council. "REN21 Renewables (2012). Global Status Report". European Focus, Paris, France (in Eng.).

[3] Kasymbekov Zh.K. Vacuum cleaning of sewer manholes using tractor exhaust gas energy // Water and Ecology: Problems and Solutions. SPb., 2018. N 2(74). P. 25-31 (in Rus.).

[4] Mukhamedzhanov M.A., Sagin J., Nurgaziyeva A.A. (2018). Relation between surface water and groundwater as the factor for formation of groundwater renewable resources on the territory of Kazakhstan // Of the national academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. N 5. P. 15-17 (in Eng.). https://doi.org/10.32014/2018.2518-170X.4

[5] Alternative energy sources in Kazakhstan // https://infourok.ru/alternativnie-istochniki-energii-v-kazahstana-2251312.html (in Rus.).

[6] Vilkovisky I.Ya. Hydropower of Kazakhstan // Current state and prospects. Almaty: Kazgidro LLP, 2007. 13 p. (in Rus.).

[7] Hydropower problems in Central Asia: a view from Kazakhstan http://stanradar.com/news/full/20425-gidroenergeticheskie-problemy-v-tsentralnoj-azii-vzgljad-iz-kazahstana.html] (in Rus.).

[8] Hydropower potential of Central Asian countries // https://studbooks.net /1726548/ekonomika/gidroenergeticheskiy_potentsial_stran_tsentralnoy_azii (in Rus.).

[9] Green economy: realities and prospects in Kazakhstan // https://sk.kz/upload /iblock/3f5/3f5f8e2087688517bcc667eeebc82630.pdf] (in Rus.).

[10] Brekke Hermod (2002). Design of hydraulic machinery working in sand laden water. Abrasive erosion and corrosion of hydraulic machinery. London (in Eng.).

[11] Neopane Hari P., Ole G. Dahlhaug, Thapa Bhola (2009). Experimentalexamination of the effect of particle size and shape in hydraulic turbines // Waterpower XVI. Spokane, Washington, USA (in Eng.).

[12] Padhy M.K., Saini R.P. (2008). A review on silt erosion in hydro turbines // Renewable and Sustainable Energy Reviews. 12(7). (in Eng.).

[13] Thapa Bhola, Brekke Hermod (2004). Effect of sand particle size and surface curvature in erosion of hydraulic turbine. IAHR symposium on hydraulicmachinery and systems. Stockholm (in Eng.).

[14] Loginov G.I. Results of studies of the winter mode of operation of water intake structures of diversion hydroelectric power plants // Science and New Technologies. Bishkek, 2016. N 1. P. 38-43 (in Rus.).

[15] Kasymbekov Zh.K., Myrzakhmetov M.M., Kasymbekov G.Zh. Small derivational hydropower plant // Patent KZ No. 25130. 2014 (in Rus.).

[16] Koshumbaev M.B. Hydroturbine // Patent KZ No. 13064. 2003 (in Rus.).

[17] Kasymbekov Zh.K., Kasymbekov G.Zh. Small derivational hydroelectric power station with hydrocyclone water treatment units // Bulletin of KazNTU named after K. I. Satpayev. 2011. N 6(88). P. 42-45 (in Rus.).

[18] Kubeysinova N., Kasymbekov Zh. Improvement of the technological scheme of a small hydro power plant using a hydrocyclone water treatment unit // Youth Scientific Forum: Technical and Mathematical Sciences. February 17, N 1(31). M., 2016. P. 58-63 (in Rus.).

[19] Belash I.G. Problems of Reliability and Efficiency of Hydraulic Turbine Equipment of Hydroelectric Power Stations // Proceedings of the Conference "Improving Reliability and Efficiency of Operation of Power Stations and Power Systems", 2011, MEI (in Rus.).

[20] Yanina Y.U., Khodankov N.A. Circulating minihydroelectric power station // Patent KZ No 29169. 2014 (in Rus.).

[21] Kasymbekov Zh.K., Atamanova O.V., Kasymbekov G.Zh. Hydro-electrostation of hydrocyclone type of small power // The Bulletin of the National academy of sciences of the Republic of Kazakhstan. 2018. Vol. 5, N 375. P. 48-54 (in Eng.). https://doi.org/10.32014/2018.2518-1467.6

[22] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[23] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[24] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

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REGULARITIES OF ROCK PRESSURE DISTRIBUTION UNDER SAFETY PILLARS AND COAL STRATUM EDGES

Abstract. The development of formation formations leads to the formation of a large number of zones of high rock pressure (HRP) in the thickness of rocks, formed by the influence of the reference pressure of the boundary parts of the massif and the pillar left on the adjacent layers. The presence of HRP zones sharply worsens the condition and preparatory workings of capital in the development of the Suite of layers. The article presents the results of the analysis of the observations in the areas of underground workings of coal mines of the Karaganda coal basin, located under the pillar and the regional parts of the overlying coal seams. The results of the studies showed that in all the workings in which observations were carried out, the height of the work site located under the whole (the regional part) varies wavelike. In the result of the analysis proved the wave nature of the stationary reference pressure and the regularities of its distribution under the pillars and boundary parts of coal seams.

Key words: bearing pressure, coal target, edge part of coal seam, zone of increased rock pressure, formation, preparatory development, harmonic process.

Introduction. It is known that the rock pressure changes gradually in areas adjacent to stratum edge (Webber wave). It's most comprehensively studied in [1] for areas adjacent to breaking face. Another study, [2], notes that the kinetics of front abutment pressure forms in a wave shape. These studies have demonstrated that the abutment pressure has an undular profile with developed periodic sequence of elevated and reduced fornt abutment pressure zones.

Reference [3] studies the undular nature of abutment pressure under safety pillars and stratum edges, reveling the damped sinusoid pressure pattern along the stratum proportional to distance from the source of abutment pressure.

Material and Methods. The analysis of these studies shows that the formation of abutment pressure has a periodic nature (damped sinusoid). The acoustic studies show that the periodic process (whether damped or continuous) can never be the result of interfering, nonlinearity of medium, dispersion or frequency dependence of whatever nature. All these processes and features of medium may cause nonlinear distortions, generate harmonic oscillations, but may never actually generate oscillations, which requires separate oscillatory system [4].

All natural sciences, as acoustics, mechanics, electrodynamics, nuclear physics deal with ocsillations. The physical nature of oscillatory processes varies widely, e.g. the oscillations of a railway bridge and the oscillations in a LC contour are of completely different nature. However even a brief study of these oscillations reveals that they have much in common. Detailed analysts shows that the oscillatory processes we observe follow the major common rules regardless of their nature [5]. This raises the question: to what extent the oscillatory process generated by the abutment pressure corresponds to the common laws of oscillatory theory, acoustics in particular.

As per acoustic data the oscillatory systems of coal stratums are uniform plane parallel lythologic units. Such resonating layers comprising of bounding lithologic units - limestone, sandstone, siltite, agryllite - are the half-wave longitudinal thickness-shear resonators, so that

$$h = \lambda/2 = V_{\phi} /2f_0 ,$$

where h - thickness of resonating layer; λ – medium specific wave length; V_{ϕ} – characteristic frequency of resonator layer; f_0 – phase velocity of compression waves.

The coal, combustible shale or liquid strata are non-resonating layers. Such non-resonating layers being merely a sound wave guide in carbonaceous rock does not distort the spectral composition of the echo of impact force applied to resonator layers.

The geoacoustic measurements use the ability of coal stratum (non-resonating layer) to acoustically decouple resonating layers located to both sides of it (top rock and bedrock). This decoupling ability allows differentiating top rock and bedrock echoes during acoustic investigation, thus making it possible to separately study features of top and bedrock.

Acoustic features of resonating layer determine the following:

- its surface oscillability;
- the amplitudes distribution over the surface of resonating layer;
- spatial distribution of own oscillations.

When applied to abutment pressure propagating under the safety pillars and stratum edges these stipulations are transformed into the following:

1) the resonating layers are presented by strong rock types (limestone, sandstone, slitstone), because the coal layer and other incompetent layers, being porous and fractures, adsorb rock pressure by inelastic deformation thus being unable to resonate.

2) coal layer and other incompetent layers do not add anything to the qualitative representation of distribution of abutment pressure due to their non-resonating nature;

3) the features of resonating layer (sandstone, slitstone) define distribution of oscillation amplitudes and their spatial distribution along the layer;

4) the wavelength of periodic process caused by redistribution of abutment pressure in resonating layer is defined routinely by the equation applicable to any halfwave P-wave resonator:

$$\lambda/2 = h_{c.p.}$$

where $h_{c.p.}$ – thickness of resonating layer, meters.

Results and discussion. Studies confirm these hypotheses. Wherever elevated rock pressure were observed it showed wave nature. The comparison of half wave length of abutment pressure $\lambda/2$ with the thickness of top rock $h_{o.k.}$ located over the mine showed direct dependence (figure 1) corresponding to the following equation:

$$\lambda/2 = h_{o.k.}$$

The intensity of manifestation of abutment pressure depends on the following factors: the thickness of rock layer located between the mine and influencing layer h_m and extracted thickness of influencing layer $m_в$. Here the extracted thickness of influencing layer defines the mass of rock supported by coal safety pillar or stratum edge. The more the thickness, the more rock is supported by safety pillar or mine edge and more severely the abutment pressure manifest. This is why it is reasonable to use the comprehensive value of the distance from the excavation to the source of abutment pressure - overworking index $K_н$:

$$K_н = h_м/m_в$$

Using this value and basing on the observations it is possible to find the dependence of the angles formed by the line connecting the border of the crests of the wave with the edge of safety pillar (stratum edge) and the plane of the influencing layer on the distance from the source of the reference pressure is determined (figure 2). This dependence shows the wave nature of abutment pressure. The waves spread from the source of abutment pressure in the depth of rock. However the elevated rock pressure is observed only in areas corresponding to crests of such waves. This is clearly seen on the curve, figure 3.

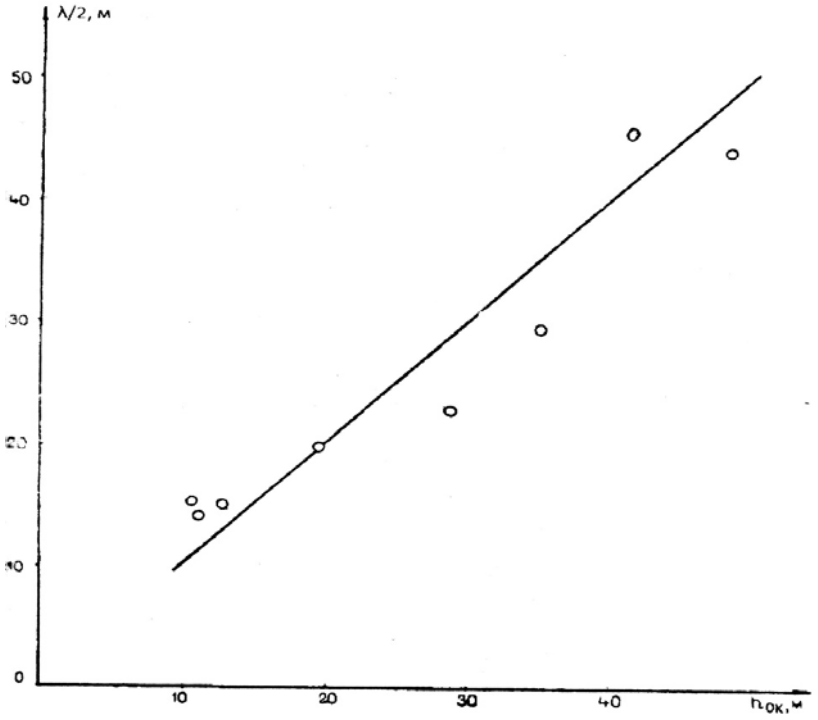

Figure 1 – Wavelength of abutment pressure λ versus toprock thickness $h_{o.к.}$

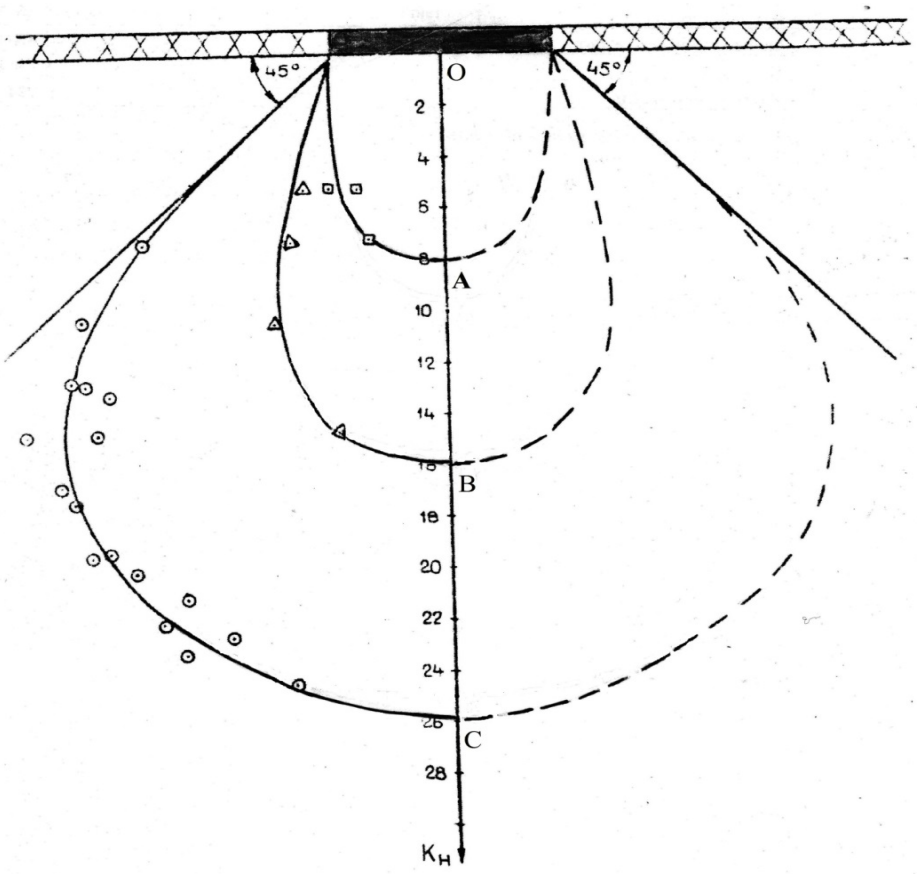

Figure 2 – The distribution of rock pressure waves above the safety pillar

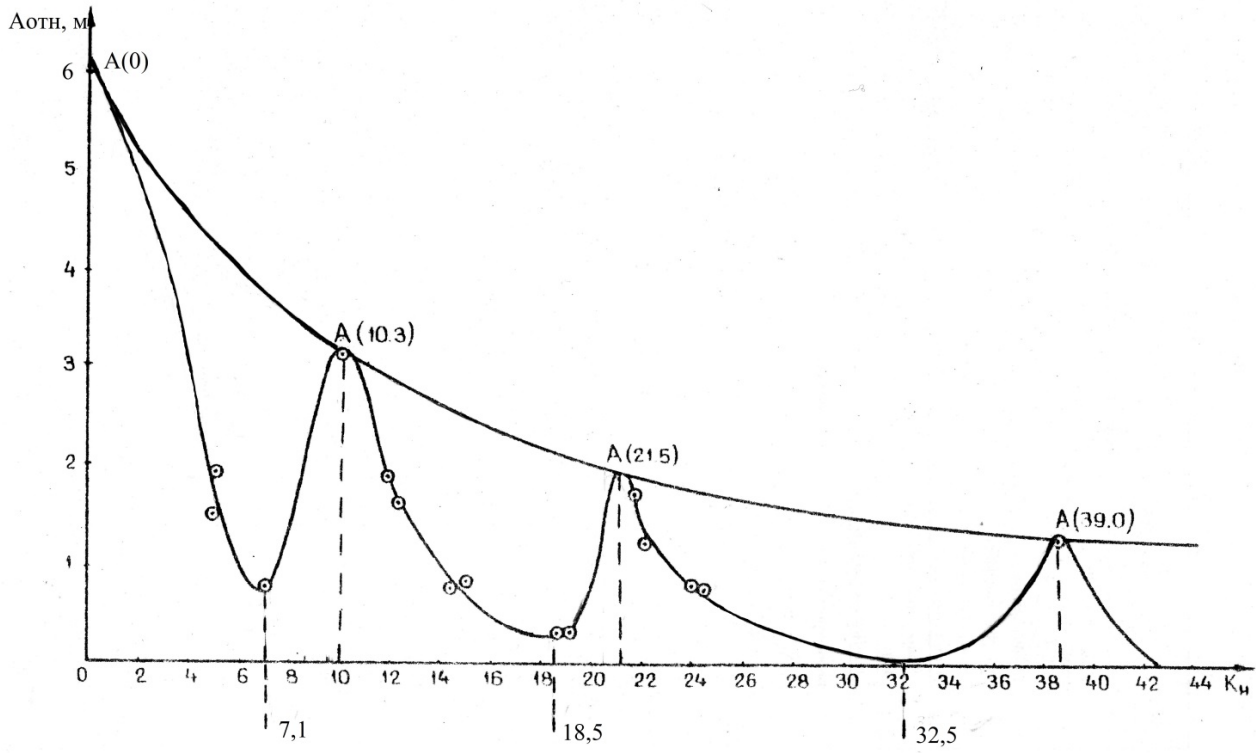

Figure 3 – The change of relative amplitude of a wave A_{om} versus the folding of overworking $K_н$

The comparison of absolute values of mine height oscillation amplitude obtained during studies is of no scientific value as the studies were performed in various conditions (absolute depth, rock composition, life time). Thus, to make comparisons of mines possible, the relative amplitude A_{om} is introduced . The relative amplitude is the ratio of maximum amplitude of the wave A_{max} to the value of decrease of mine height during its life time outside of abutment pressure zone A_0 (i.e. the difference between the original mine height and the height of mine where the wave axis is located). This allows to null out the differences of actual rock conditions and only take into consideration the influence of abutment pressure. The dependence of relative amplitude A_{om} on the distance from the abutment pressure source $K_н$ shows the same crests of pressure waves as on the figure 2, and also shows the areas subject to elevated rock pressure. As seen from the graph the areas subject to elevated rock pressure are interleaved by the areas free from rock pressure [9].

The dependencies represented on figures 2 and 3 allow to find yet another regularity in distribution of abutment pressure. The distances AO, BO and CO (figure 2) are in the following relationship:

$$AO/BO = 8/16 = 0,5;$$

$$BO/CO = 16/25,9 = 0,618,$$

i.e. they agree with the sequence stated in [6] for the zones of higher strength adjacent to mine according to the following equation:

$$X^{n+1} + X - 1 = 0, \quad (1)$$

where X – the ratio of the distance from the edge of previous zone to the edge of the following zone of elevated rock pressure, and n – ordinal number of the zone counting form the base of safety pillar.

The exact values of (1) are given in table 1.

Table 1 – The roots of equation (1)

n	0	1	2	3	4	5	6	7	8
X	0.50	0.6180	0.6823	0.7245	0.7549	0.7781	0.7965	0.8117	0.8243

The values of relative amplitudes of wave crests (figure 3) are also connected by this consequense:

$$A_{(10,3)} / A_{(0)} = 3,1/6,2 = 0,5;$$

$$A_{(21,5)} / A_{(10,3)} = 1,92/3,1 = 0,619;$$

$$A_{(39,0)} / A_{(21,5)} = 1,31/1,92 = 0,682.$$

The distances *R* to minimums of relative amplitudes of the wave follow the below equation:

$$7.1/18.5 = 0,384$$

$$18,5/32,5 = 0,569$$

i.e. they agree with the sequence stated in [7;8] for the zones of lower strength (fractured zones) adjacent to mine during their zonal disintegration according to the following equation:

$$X^{n+1/2} + X - 1 = 0 \quad (2)$$

The exact values of (2) are given in table 2.

Table 2 – The roots of equation (2)

n	0	1	2	3	4	5	6	7	8
X	0.3820	0.5698	0.6540	0.7055	0.7408	0.7654	0.7894	0.8039	0.8182

This correspondence shows that these zones are the zones free from rock pressure, because they fall onto the lower strength (fractured) zones adjacent to mine during their zonal disintegration

Conclusions. Thus, the revealed wave nature regularities of distribution of rock pressure above (under) safety pillars and stratum edges allow predicting the zones of elevated rock pressure and its manifestation in such zones. The identification of patterns of pressure redistribution above (under) the safety pillars and stratum edges of coal layers will allow to develop reliable methods and recommendations for the identification of elevated rock pressure zones for investigation and producing mines, reduce the length of mines located in the zones influenced by safety pillars and stratum edges of adjacent layers, due to scientifically grounded determination of the configuration and range of influence of elevated rock pressure zones and, as a result, will significantly reduce the cost of managing rock pressure in the investigation and producing mines during excavation of coal strata.

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КӨМІР ПЛАСТАРЫНЫҢ ЖИЕГІНДЕГІ БӨЛІКТЕР МЕН ТІРЕКТЕР АСТЫНДАҒЫ ҚОЛДАУ ҚЫСЫМЫН ТАРАТУ ЗАҢДЫЛЫҒЫ

Аннотация. Пластар свитасын әзірлеу тау жыныстарының қалыңдықтарында үлкен мөлшерде тау-кен қысымының жоғарлауы ТКҚЖ шекарасының түзілуіне алып келеді, ол дегеніміз көрші пластардан қалған массив пен тірек жиектеріндегі қысым әсерінен пайда болған. ТКҚЖ тау-кен қысымының жоғарлау шекарасы пластар свитасын әзірлеу барысында капиталды және дайындалған өңдеулер жағдайын шұғыл түрде нашарлатады. Бұл мақалада жоғарғы жатқан көмір пластарының жиектері мен тірек астындағы Қарағанды көмір бассейні көмір шахтасының жер асты өңдеулері аймағында жүргізілген талдау нәтижелері келтірілді. Жүргізілген зерттеулер нәтижелері көрсеткендей, яғни тіреу астында орналасқан барлық қаралған өңдеулер аймақтарының ұзындығы толқынға ұқсас өзгеріп отырады. Жүргізілген талдау нәтижесінде стационарлы қысымның толқынды өзгеру сипаттамасы дәлелденді және оның көмір пластарының жиектері мен тіреулер астарында таралу заңдылығы анықталды.

Нүйін сөздер: қолдау қысымы, көмір тіреулері, көмір пластарының жиек бөліктері, тау-кен қысымының жоғарғы шекарасы, пластар свитасы, дайындалған өңдеулер, гармоникалық үрдіс.

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ЗАКОНОМЕРНОСТИ РАСПРОСТРАНЕНИЯ ОПОРНОГО ДАВЛЕНИЯ ПОД ЦЕЛИКАМИ И КРАЕВЫМИ ЧАСТЯМИ УГОЛЬНЫХ ПЛАСТОВ

Аннотация. Разработка свит пластов приводит к образованию в толще пород большого количества зон повышенного горного давления (ПГД), образованных влиянием опорного давления краевых частей массива и целиков, оставленных на соседних пластах. Наличие зон ПГД резко ухудшает состояние подготовительных и капитальных выработок при разработке свит пластов. В статье приводятся результаты анализа проведенных наблюдений на участках подземных выработок угольных шахт Карагандинского угольного бассейна, находящихся под целиками и краевыми частями вышележащих угольных пластов. Результаты проведенных исследований показали, что во всех выработках, в которых проводились наблюдения, высота участка выработки, расположенного под целиком (краевой частью) изменяется волнообразно. В результате проведенного анализа доказан волновой характер стационарного опорного давления и выявлены закономерности его распространения под целиками и краевыми частями угольных пластов.

Ключевые слова: опорное давление, целик угля, краевая часть угольного пласта, зона повышенного горного давления, свита пластов, подготовительная выработка, гармонический процесс.

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REFERENCES

[1] Chernyak I.L., Burchakov Yu.I. Management of mining pressure in the preparatory workings of deep mines. M.: Nedra, 1984. 300 p.

[2] Kuzyara V.I., Kolesnikova V.G., Komlev E.S., Svetlichnyy V.N. Regularities of formation of the reference pressure ahead of mines) // Ugol Ukrainy. 1990. N 11. P. 15-16.

[3] Lis S.N. The results of studies of the wave nature of the bearing pressure under the pillars and boundary parts of coal seams // Gornyy zhurnal Kazakhstana. 2018. N 7. P. 23-27.

[4] Primeneniye i ispolzovaniye apparatury «Rezonans» – Metodicheskiye rekomendatsii (Application and use of the equipment "Resonance" – Methodical recommendations). L.: LGI, 1987. 102 p.

[5] Strelkov S.P. Introduction to the theory of oscillations. M.: Nedra, 1964. 437 p.

[6] Lis S.N., Varekha Zh.P. Patterns of disintegration of rocks close to the capital and preparatory workings // Kompleksnoye ispolzovaniye mineralnogo syria. 2012. N 2. P. 23-29.

[7] Lis S.N., Varekha Zh.P. Patterns of disintegration of rocks close to the capital and preparatory workings // Gornyy zhurnal Kazakhstana. 2013. N 9. P. 14-18.

[8] Lis S.N. Patterns of disintegration of rocks close to the capital and preparatory workings // Energeticheskaya bezopasnost Rossii: novyye podkhody k razvitiyu ugolnoy promyshlennosti: Sbornik trudov XV mezhdunarodnoy nauchno-prakticheskoy konferentsii. 8–11 oktyabrya 2013. Kemerovo: KVK «Ekspo-Sibir», 2013. P. 155-158.

[9] Seitmuratova E.Yu., Zeylik B.S., Dautbekov D.O., Baratov R.T. // National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 6, N 432. P. 210-220. ISSN 2224-5278. https://doi.org/10.32014/2018.2518-170X.51

[10] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al.Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

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PARTICULARITIES OF MULTI-CUTTER CUTTING DYNAMICS

Abstract. Certain particularities of steady continuous cutting dynamics for multi-cutter turning and the results of mathematical modeling are discussed in the paper. The effect of processing parameters on the excitation of vibration in the case of multi-cutter turning of a long cylindrical part with finite flexibility is studied. Depending on the fixing rigidity of the cutters and their relative positioning, different forms of the tool oscillation and formed chips are analyzed.

The model is based on equations of motion and the cutting law in the form of a fractional function together with the equation for new surfaces formation which are represented as a system of differential-algebraic equations with several delays describing the dynamics of multi-cutter turning. These equations allow consider the regenerative mechanism of oscillations excitation in the system. The evolution of the cutter's oscillations to steady regime in the case of an angular shift of the cutters, as well as the evolution of chips are shown in the work. An example of the operation of cutters, which angular shift allows to control the work of the cutting edges is given. The reasons for the stability loss and the self-oscillations excitation are noticed. The procedure for integrating systems of differential-algebraic equations with retarded argument and the model of two-cutter turning taking into account the compliance of the cutting tool fixation is considered.

Influence of the technological system parameters on the stability of continuous cutting regime is analyzed.

Key words: multi-cutter turning, dynamics, modelling, continuous cutting, discontinuous cutting, self-excited vibration, stability, time-delay.

Introduction. The turning of parts is often accompanied by the occurrence of self-oscillations in the "machine-tool-workpiece" system, which adversely affects the quality of the parts produced and the equipment wear. Various reasons for their occurrence, in particular, caused by the nonlinearity of cutting forces, compliance of the machine elements or the part itself, cutting tool fastening conditions, turning along the surface formed on the previous revolution of the part (or tool), thermomechanical effects in the cutting zone, and etc. are detailed in modern literature [1-10]. Under certain conditions, turning with constant thickness of the removed layer (chips) can become dynamically unstable. General questions of the onset of the oscillations during cutting have been discussed in numerous works [1, 11, 12].

One of the reasons for the stability loss and the self-oscillations excitation is the nonlinearities of both the cutting forces and the frictional forces (in particular, when the flank face of the cutter is rubbed), which depend on the cutting speed and the thickness of the layer to be removed and which lead to chips discontinuity [13-15]. Other reasons for stability loss are the regenerative chatter, i.e. time delay between two subsequent tools, the workpiece compliance, temperature effects, etc. [4, 16-19].

Problem formulation. At the same time, due to the development of various non-classical cutting schemes, in particular, using multiple cutters simultaneously, a number of new problems related to the

analysis of the dynamics of the multi-cutter cutting process arise [20-25]. Note that multi-cutter turning allows combining different types of processing (roughing and finishing), the cutting depth (the thickness of the layer to be removed) in one pass can be increased, the transverse components of cutting forces can be balanced (which is important especially for turning long parts), manufacturing time is significantly shortened [26, 27]. In a number of cases such a scheme of processing makes it possible not to use intermediate support elements with simultaneous increase in the cutting depth.

The aim of this paper is to determine the conditions for self-excitation of oscillations and to estimate the possibility of realizing a continuous (segmentation-free) cutting. For this purpose, the effect of processing parameters on the excitation of vibration in the case of multi-cutter turning of a long cylindrical part with finite flexibility is studied. In the case of multi-cutter turning, the axial (along the longitudinal axis of the workpiece) displacement (vibration) of the cutters has an important role in the appearance of extremely undesirable vibration regimes (the phenomenon of dynamic instability). Depending on the fixing rigidity of the cutters and their relative positioning, different forms of oscillation of the tool and formed chips may occur.

Mathematical model of the multi-cutter turning. Let us consider the workpiece as an absolutely rigid body of cylindrical shape with the machined surface of radius R and length l. The workpiece rotates around its longitudinal axis with constant angular velocity ω (figure 1,*a*). The processing is carried out simultaneously by n cutters located along the circumference of the workpiece at an angle $\varphi_j (j = \overline{1,n})$ to each other so that $\sum_1^{j=n} \varphi_j = 2\pi$. All the cutters are fixed to a single support moving along the workpiece longitudinal axis with constant velocity V (figure 1,*b*). Each j-th cutter is considered as a rigid body independently fixed in a separate toolholder with finite stiffness in axial direction. For the sake of clarity of the results obtained, we shall limit ourselves to considering only the longitudinal (along the axis of the workpiece) components of the cutting forces and displacements of the cutter.

Note that all the subsequent reasoning and mathematical calculations are also valid for the case of longitudinal feed of a workpiece and a rotating support.

Mathematical model of nonlinear dynamics of the process under consideration can be described by the system consisted of three groups of equations: equations of technological system motion, cutting law and equations of new surfaces formation [7, 9, 11, 15, 21, 23].

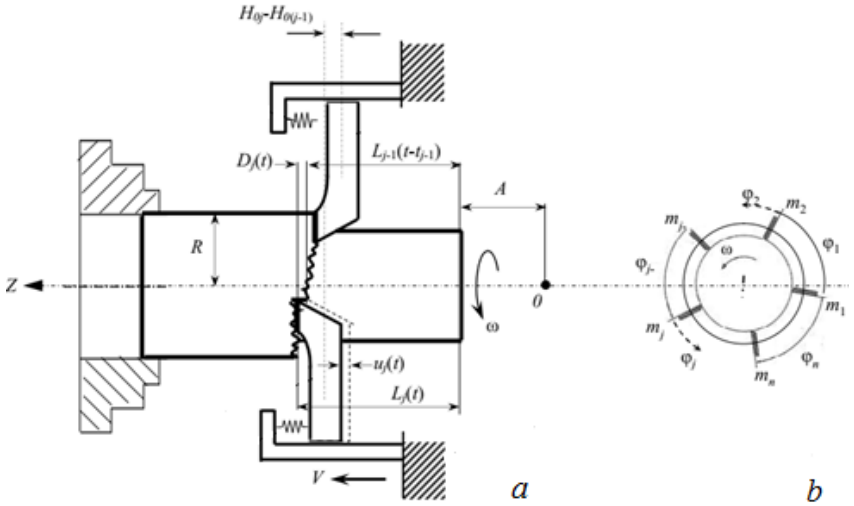


Figure 1 – Design scheme of multi-cutter turning

Equations of motion, describing vibration of the cutters in longitudinal direction could be written as follows [11-13, 15]:

$$m_j \ddot{u}_j = -d_j \dot{u}_j - k_j u_j + F_j\left(t, h_j\right); \quad j = \overline{1,n} \tag{1}$$

where m_j is mass of the j-th cutter, d_j and k_j are coefficients of damping and stiffness of the j-th cutter attachment, respectively; $u_j(t)$ is axial displacement of the j-th cutter relative to the nominal (quasistatic) state; $h_j(t)$ is cutting chips thickness removed by the j-th cutter.

Cutting law for every *j*-th cutter is described by the cutting law model in the form of a fractional function [7, 17, 20]:

$$F_j(t) = K_0 h_j(t) \frac{c + r h_j(t)}{c + h_j(t)}, \quad j = \overline{1,n} \tag{2}$$

where $K_0 = \gamma \sigma_L B$ is static cutting stiffness, σ_L is characteristic stress of the processed material; B is a width of the removed layer (chips); γ, r, c are experimentally determined coefficients. Thickness $h_j(t)$ of the material removed by the *j*-th cutter at multi-cutter cutting depends on the workpiece surface geometry, formed at cutting by the previous *(j*-1*)*-th cutter.

New surfaces formation equations, forming by the *j*-th cutter, are the functions of time *t* measured from the free (untreated) end of the workpiece. Herewith the *j*-th cutter processes the surface formed by the previous *(j*-1*)*-th cutter, at the moment $\left(t_j - t_{j-1}\right)$. Time t_{j-1} is a delay, equal to the time of turning the part by the angle between the cutting edges $t_{j-1} = \varphi_{j-1}/\omega$. These features can be described by equations of new surfaces formation in the following form [7, 9, 15]:

$$\begin{cases} D_j(t) = Vt - u_j(t) - L_{j-1}\left(t - t_{j-1}\right) + A - H_{0j}, \\ h_j(t) = \max\left[0, D_j(t)\right], \\ L_j(t) = L_{j-1}\left(t - t_{j-1}\right) + h_j(t), \end{cases} \tag{3}$$

where (see figure 1,*a*): $D_j(t)$ is the distance between cutting edge of the j-th cutter and the surface treated by the previous *(j-1)*-th cutter at the moment $t - t_{j-1}$; $L_j(t)$ is the distance from the right end of the part to the surface generated by the *j*-th cutter; *A* stands for the distance measured from the initial position of the cutting edge of the first cutter to the right end of the workpiece; H_{0j} is the axial offset of *j*-th cutter relative to the first one, for which the distance *A* is measured; *t* stands for current time.

Equations {(1) - (3)} are a system of differential-algebraic equations with several delays describing the dynamics of multi-cutter turning. These equations allow considering the regenerative mechanism of oscillations excitation in the system: a new surface resulting on the current processing cycle contains information about all previous tool passes.

Let us reduce the system of equations {(1) - (3)} to dimensionless form by taking the feed per revolution h_0 as a linear scale X_*, as a time scale $T_* = \sqrt{\sum_{i=1}^{n} T_i^2/n}$, $T_i = 2\pi\sqrt{m_j/k_j}$, T_i is a period of the cutters natural oscillations; as a cutting force scale $F_* = K_0 h_0$.

Then in case of the identical cutters and equality of their fixing conditions $\left(m_i = m, k_i = k, d_i = d, T_i = T = T_*, i = \overline{1,n},\right)$ the equations in dimensionless form take the form:

$$\begin{cases} \Delta_j(\tau) = \tau/\rho - \xi_j(\tau) - \Lambda_{j-1}\left(\tau - \tau_{j-1}\right) + \mathrm{A} - \mathrm{H}_{0j}, \sum_{j=1}^{n} \tau_j = \rho, \\ \eta_j(\tau) = \max\left(0, \Delta_j(\tau)\right), \Pi_j = \eta_j\left(\eta_* + r\eta_j\right) / \left(\eta_* + \eta_j\right) \\ 0 = -\Lambda_j(\tau) + \Lambda_{j-1}\left(\tau - \tau_{j-1}\right) + \eta_j(\tau), \\ \xi_j'' = -4\pi\varsigma\xi_j' - 4\pi^2\xi_j + 4\pi^2\kappa\Pi_j, j = \overline{1,n} \end{cases} \tag{4}$$

where the following dimensionless quantities and complexes are introduced:

$$\xi_j = \frac{u_j}{h_0}, \varsigma = \frac{d}{2\sqrt{mk}}, \kappa = \frac{K_0}{k}, \eta_j = \frac{h_j}{h_0}, \eta_* = \frac{c}{h_0}, \Pi_j = \frac{F_j}{K_0 h_0},$$

$$\Lambda_j(\tau) = \frac{L_j}{h_0}, \Delta_j = \frac{D_j}{h_0}, c = \frac{2\pi}{\omega T_*}, \mathrm{A} = \frac{A}{h_0}, \mathrm{H}_{0j} = \frac{H_{0j}}{h_0} \tag{5}$$

ρ is ratio of the cutters natural frequency to the frequency of the workpiece rotation and equals to the dimensionless time of one revolution of the workpiece (the parameter 1/ρ is a dimensionless cutting speed); *k* is relative static cutting stiffness, which, in this case, are the same for the zones of interaction between the cutters and the workpiece; Π_j is a dimensionless axial component of the cutting force.

Two-cutter turning. In the particular case of two-cutter turning, the cutters divide the circumference of the workpiece cross-section into two unequal parts (figure 2), which are determined by the angles $\varphi_1 = \pi + \Delta\varphi$ and $\varphi_2 = \pi - \Delta\varphi, \Delta\varphi$ is deviation of the angle between the cutters from π.

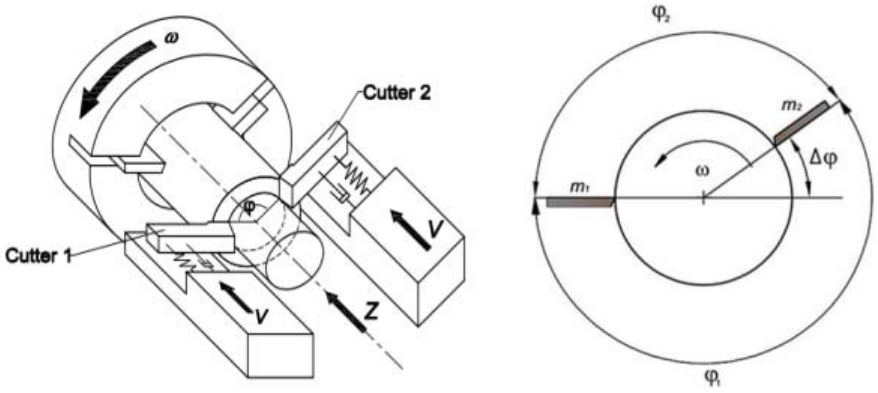


Figure 2 – Design scheme of two-cutter turning

The dynamics equations (4) for two-cutter turning are written in the following form:

$$\begin{cases} \Delta_j(\tau) = \frac{\tau}{\rho} - \xi_j(\tau) - \Lambda_j(\tau - \tau_j) + \mathrm{A} - (j-1)\mathrm{H}_0, \\ \eta_j(\tau) = \max\left(0, \Delta_j(\tau)\right), \Lambda_j(\tau) = \Lambda_j(\tau - \tau_j) + \eta_j(\tau), \\ \Pi_j = \eta_j\left(\eta_* + r\eta_j\right) / \left(\eta_* + \eta_j\right) \\ \ddot{\xi_j} = -4\pi\varsigma\dot{\xi_j} - 4\pi^2\xi_j + 4\pi^2\kappa\Pi_j, j = 1,2; J = \mathrm{mod}(j-2,2) + 1 \end{cases} \tag{6}$$

with the initial condition $\Lambda_{j0}(0) = \Lambda_{j0}(-\tau_j)$. In this case, the values of the delays are normalized as follows: $\tau_1 = \rho\varphi_1/2\pi, \tau_2 = \rho\varphi_2/2\pi, \rho = \tau_1 + \tau_2$.

Continuous cutting is characterized by the fact that $\Delta_{1,2}(\tau) \geq 0 \forall \tau$. In this case the complete system of equation (6) can be simplified, and we may consider only the equations for the cutters deviations:

$$\begin{gathered} \ddot{\xi_j}(\tau) = -4\pi\varsigma\dot{\xi_j}(\tau) - 4\pi^2\xi_j(\tau) + 4\pi^2\kappa\Pi_j(\tau), \\ \Pi_j(\tau) = \eta_j\left(\eta_* + r\eta_j(\tau)\right) / \left(\eta_* + \eta_j(\tau)\right), \\ \eta_j(\tau) = \frac{\tau_j}{\rho} + \xi_j(\tau - \tau_j) - \xi_j(\tau), j = 1,2, J = \mathrm{mod}(j-2,2) + 1 \end{gathered} \tag{7}$$

Stationary continuous turning is an unperturbed motion $\left(\xi_j(\tau) = \xi_{j0} = const, \eta_j = \eta_{j0} = const\right)$, for which the parameters of the removing layer thickness are determined by the following relationships:

$$\begin{gathered} \eta_{10} = \tau_2/\rho - \xi_{10} + \xi_{20} + \mathrm{H}, \eta_{20} = \tau_1/\rho - \xi_{20} + \xi_{10} - \mathrm{H} \\ \Pi_{j0} = \eta_{j0}\frac{\eta_* + r\eta_{j0}}{\eta_* + \eta_{j0}}, \xi_{j0} = \kappa\Pi_{j0}, j = 1,2 \end{gathered} \tag{8}$$

Equations in variations near the unperturbed motion (8) for equations (7) have the form

$$\begin{cases} \delta\xi_1'' + 4\pi\varsigma\delta\xi_1' + 4\pi^2\delta\xi_1 = 4\pi^2\kappa\rho_1\left(-\delta\xi_1(\tau) + \delta\xi_2(\tau-\tau_2)\right), \\ \delta\xi_2'' + 4\pi\varsigma\delta\xi_2' + 4\,'\pi^2\delta\xi_2 = 4\pi^2\kappa\rho_2\left(-\delta\xi_2(\tau) + \delta\xi_1(\tau-\tau_1)\right). \end{cases} \tag{9}$$

$$\rho_j = \left.\frac{\partial\Pi_j}{\partial\eta_j}\right|_{\eta_j=\eta_{j0}} = r + \frac{\eta_*^2(1-r)}{\left(\eta_* + \eta_{j0}\right)^2}, j = 1{,}2$$

The characteristic equation is obtained from (9) by substituting the solution in the form of $\delta\xi_j = \exp(\lambda\tau)C_j$:

$$\begin{gathered} P(\lambda;\varsigma,\rho,\kappa) = \cdots \\ = [\lambda^2 + 4\rho\varsigma\lambda + 4\pi^2(1+\kappa\rho_1)][\rho\lambda^2 + 4\pi\varsigma\lambda + 4\pi^2(1+\kappa\rho_2)] - \cdots \\ \ldots - 16\pi^4\kappa^2\rho_1\rho_2\exp(-\lambda\rho) = 0. \end{gathered} \tag{10}$$

On the boundaries of the motion stability regions (8), the characteristic value λ is equal to the purely imaginary value $\lambda = 2\pi is, s \in \mathbb{R}$. From equation (10) the boundaries $\{\kappa(s), \rho(s)\}$ can be found in parametric form (figure 3):

$$\Gamma = \left\{\kappa(s), \rho(s) \middle|\ \mathrm{Re}\left(P(is;\varsigma,\rho,\kappa)\right) = 0, Im\left(P(is;\varsigma,\rho,\kappa)\right) = 0, s \in (0,\infty)\right\} \tag{11}$$

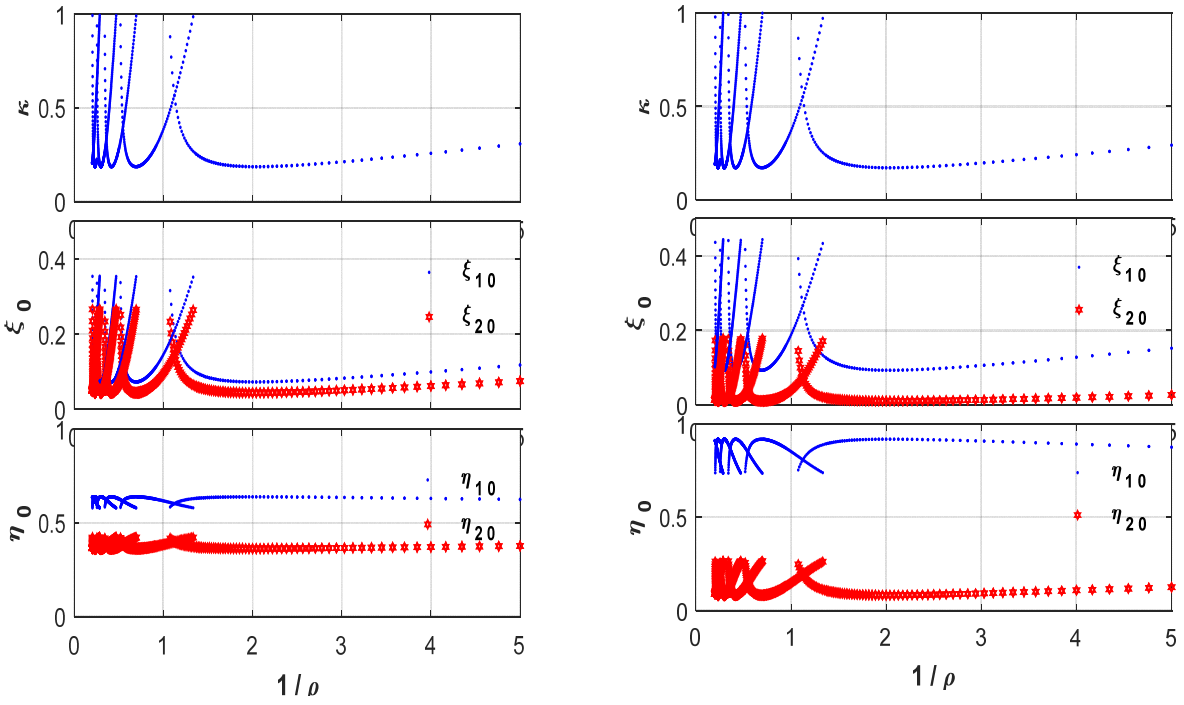


Figure 3 – Different representations of the stability diagram:
a: $\{\tau_1/\tau_2 = 2, H = 0, \eta_* = 0.1, \varsigma = 0.05, r = 0.55\}$, b: $\{\tau_1/\tau_2 = 1, H = 0.5, \eta_* = 0.1, \varsigma = 0.05, r = 0.55\}$

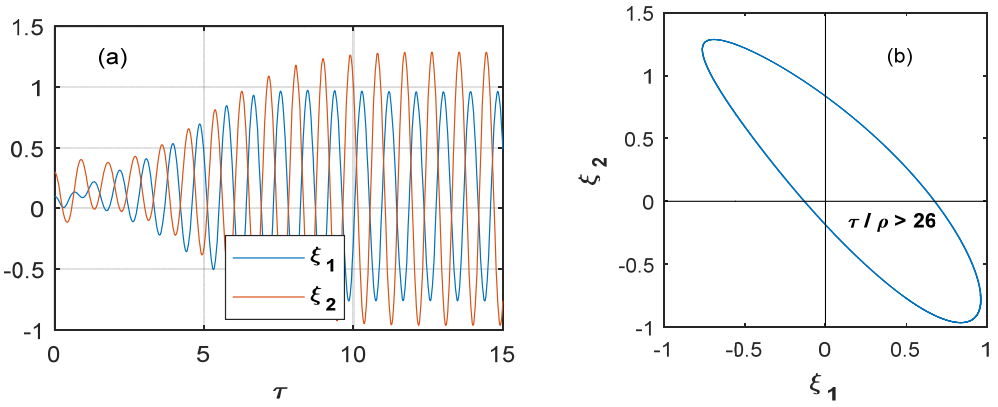
It should be noted that the quantities κ, ρ appear in **Ошибка! Источник ссылки не найден.** both explicitly and indirectly via $\rho_j\eta_{j0}, \xi_{j0}$. That is, the equations {**Ошибка! Источник ссылки не найден. -Ошибка! Источник ссылки не найден.**} are to be solved together when calculating the stability boundaries **Ошибка! Источник ссылки не найден.**.

Intermittent cutting numerical modelling. The complete system of equations of dynamics (6) is a system of differential-algebraic equations with retarded argument. For numerical integration, it is transformed into a system of differential equations with retarded argument: **ddae**– **dde** [17].

$$\begin{cases} \varepsilon \Lambda_j'(\tau) = \Lambda_j(\tau) + \Lambda_j(\tau - \tau_j) + \eta_j(\tau) \\ \xi_j'' = -4\pi\varsigma\xi_j' - 4\pi^2\xi_j + 4\pi^2\kappa\Pi_j, j = 1,2, J = \mathrm{mod}(j-2,2) + 1 \end{cases} \quad (12)$$

$$\begin{cases} \Delta_j(\tau) = \tau/\rho - \xi_j(\tau) - \Lambda_j(\tau - \tau_j) + A - (j-1)\mathrm{H} \\ \eta_j(\tau) = \max\left(0, \Delta_j(\tau)\right);\ \Pi_j = \eta_j\left(\eta_* + r\eta_j\right)/\eta_* + \eta_j \end{cases}$$

Consider the cutting process, corresponding to the working point $\{\kappa = 0.5, \rho = 0.5\}$ in the diagrams in figure 3.

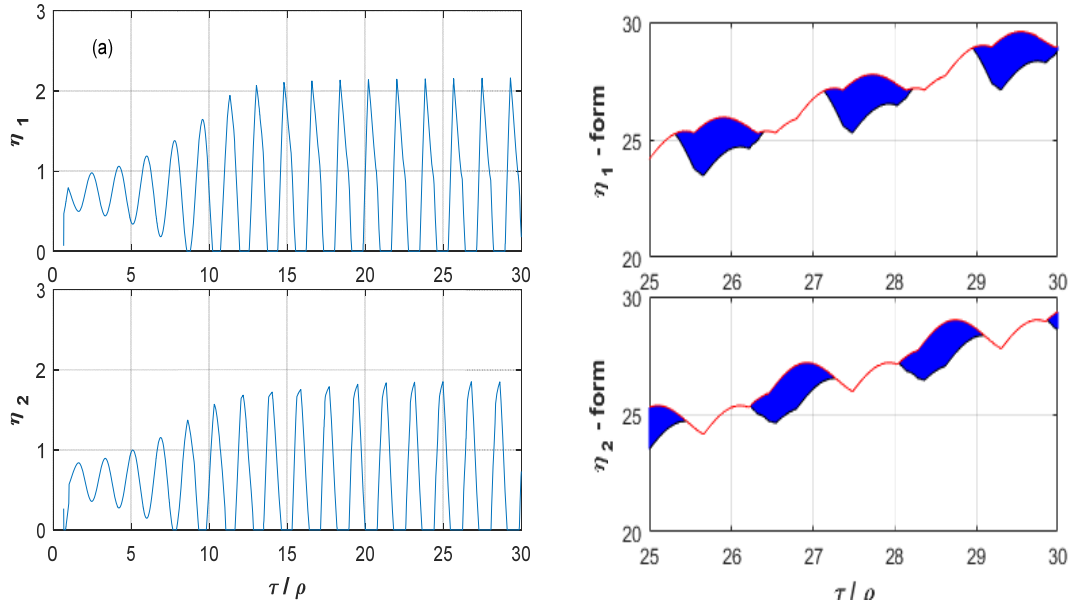


a *b*

Figure 4 – Cutters oscillations (*a*), synchronization of two cutters oscillations (*b*)

Figure 4 shows the evolution of the cutter's oscillations to steady regime in the case of an angular shift of the cutters by $240°(\tau_1/\tau_2 = 2)$. Vibration stabilizes in about 15 workpiece rotations. Then the oscillations syncroniz (figure 4,*b*).

Figure 5 shows the evolution of the chips under the same conditions. One can see that the cutters work differently. Angle shift of the cutters allows controlling the work of the cutting edges.



a *b*

Figure 5 – The chips thickness (*a*) and the cross-sectional shape of the chips changing (*b*)

Conclusions. The considered model of two-cutter turning taking into account the compliance of the cutting tool fixation allows one:

- To investigate parametrically the stability of continuous stationary turning.
- To study the effect of axial and angular relative disposition of the cutters on the stability and the process of chips formation.
- Using the reduction of algebraic evolution equations to singular differential equations allows using standard procedures for integrating systems of differential equations with retarded argument (dde23 in MATLAB)

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КӨП КЕСКІШ КЕСУ ДИНАМИКАСЫНЫҢ ЕРЕКШЕЛІКТЕРІ

Аннотация. Жұмыста көп кескішті қайрау кезінде үздіксіз кесу үрдісінің динамикасының ерекшеліктері және математикалық моделдеудің нәтижелері талқыланады. Созылған цилиндрлік бөлшектің көп кескіш нүктесінде өңдеу параметрлерінің дірілдің қозуына әсері зерттеледі. Кескіштердің бекітілу қаттылығына және олардың өзара орналасуына байланысты кескіштің және түзілетін жоңқаның тербелісінің әртүрлі формалары талданады.

Модельдеудің негізіне қозғалыс теңдеулері, бөлшектік-рационалды функция түріндегі кесу заңы және бірнеше кешігуі бар дифференциалды-алгебралық теңдеулер жүйесі болып табылатын жаңа беттердің түзілу теңдеулері алынған және із бойынша көп кескіш нүктенің динамикасын сипаттайды. Бұл теңдеулер жүйедегі тербелістерді қозудың регенеративті механизмін ескеруге мүмкіндік береді. Жұмыста кескіштердің бұрыштық жылжуы кезінде тұрақты тербеліске шығуының эволюциясы көрсетілген, жоңқаның эволюциясы көрсетілген, кескіштердің бұрыштық ығысуы кескіш жиектерінің жұмысын басқаруға мүмкіндік беретін кескіштердің жұмысының мысалы келтірілген. Жұмыста орнықтылықты жоғалту және автотербелістердің қозу себептері атап өтілді. Дифференциалдық теңдеулер жүйесін кешіктіретін аргументпен интегралдау процедурасы көрсетілген, кескіштердің бекітілуін ескере отырып, екі кескіш нүктенің моделі қарастырылған.

Технологиялық жүйе параметрлерінің үзілісіз кесу режимінің тұрақтылығына әсері талданады.

Түйін сөздер: көп кескішті қайрау, динамика, модельдеу, үзілісіз кесу, автотербелістер, тұрақтылық, кешігу.

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ОСОБЕННОСТИ ДИНАМИКИ МНОГОРЕЗЦОВОГО РЕЗАНИЯ

Аннотация. В работе обсуждаются особенности динамики процесса непрерывного резания при многорезцовом точении и результаты математического моделирования. Исследуется влияние параметров обработки на возбуждение вибрации при многорезцовом точении протяженной цилиндрической детали. В зависимости от жесткости крепления резцов и их взаимного расположения анализируются различные формы колебаний резца и образующейся стружки.

В основу моделирования положены уравнения движения, закон резания в виде дробно-рациональной функции и уравнения образования новых поверхностей, которые представляют собой систему дифференциально-алгебраических уравнений с несколькими запаздываниями и описывают динамику многорезцового точения по следу. Эти уравнения позволяют учитывать регенеративный механизм возбуждения колебаний в системе. В работе показана эволюция выхода резцов на стационарные колебания при угловом сдвиге резцов, показана эволюция стружки, приводится пример работы резцов, угловой сдвиг которых позволяет управлять работой режущих кромок. В работе отмечены причины потери устойчивости и возбуждения автоколебаний. Показана процедура интегрирования систем дифференциальных уравнений с запаздывающим аргументом, рассмотрена модель двухрезцового точения с учетом податливости крепления резцов.

Анализируется влияние параметров технологической системы на устойчивость непрерывного режима резания.

Ключевые слова: многорезцовое точение, динамика, моделирование, непрерывное резание, автоколебания, устойчивость, запаздывание.

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REFERENCES

[1] Smith G.T. (2008) Cutting Tool Technology. Industrial Handbook. Springer – Verlag, 599 p. ISBN 978-1-84800-205-0

[2] Ozlu E., Budak E. (2009) Comparison of one-dimensional and multi-dimensional models in stability analysis of turning operations // Machine Tools and Manufacture. 47. P. 1042-1047. doi:10.1007/s10409-013-0097-z (in Eng.).

[3] Dassanayake A.V., Suh C.S. (2008) On nonlinear cutting response and tool chatter in turning operation // Communications in Nonlinear Science and Numerical Simulation. 13. P. 979-1001 (in Eng).

[4] Astashev V.K., Korendyasev G.K. (2012) Thermomechanical model of the occurrence of oscillations in metal cutting // J. of Machinery Manufacture and Reliability. 41(3). P. 189-193. doi:10.3103/S105261881203003X (in Eng.).

[5] Chen C.K., Tsao Y.M. (2006) A stability analysis of regenerative chatter in turning process without using tailstock // Advanced Manufacturing Technology. 29. P. 648-654 (in Eng.).

[6] Otto A., Khasawneh F.A., Radons G. (2015) Position-dependent stability analysis of turning with tool and workpiece compliance // Advanced Manufacturing Technology. 79(9-12). P. 1453-1463 (in Eng.).

[7] Gerasimenko A.A., Guskov M.A., Gouskov A.M., Lorong Ph., Panovko G.Ya. (2016) Analytical approach of turning thin-walled tubular parts. Stability analysis of regenerative chatter // Vibroengineering Procedia. 8. P. 179-184 (in Eng.).

[8] Wang X., Feng C.X. (2002) Development of Empirical Models for Surface Roughness Prediction in Finish Turning // Advanced Manufacturing Technology. 20(5). P. 348-356 (in Eng.).

[9] Gouskov A.M., Voronov S.A., Paris H., Batzer S.A. (2002) Nonlinear dynamics of a machining system with two interdependent delays // Communications in Nonlinear Science and Numerical Simulation. 7(3). P. 207-221. doi:10.1016/S1007-5704(02)00014-X (in Eng.).

[10] Sherov K.T., Sikhimbayev M.R., Absadykov B.N., Sikhimbayeva D.R., Buzauova T.M., Karsakova N.G., Gabdysalyk R. (2018) Control's accuracy improvement and reduction of labor content in adapting of ways of metalcutting tools // News of the National academy of sciences of the Republic of the Kazakhstan. Series of geology and technical sciences. Vol. 6(432). P. 170-177. https://doi.org/10.32014/2018.2518-170X.47 (in Eng.).

[11] Kozochkin M.P. (2013) Dynamic of cutting process. Theory, experiment, analysis. Lambert Academic Publishing. ISBN 978-3-659-42793-0 (in Rus.).

[12] Kudinov V.A. (1967) Dynamics of machine tools. M.: Mashinostroenie. 357 p. (in Rus.).

[13] Kondratenko K.A., Gouskov A.M., Guskov M.A., Lorong Ph., Panovko G.Ya. (2014) Analysis of indirect measurement of cutting forces turning metal cylindrical shells. Proceedings of Proceedings of VETOMAC X, Manchester, UK. P. 929-937. doi:10.7463/0214.0687971

[14] Lamikiz A., Lopez de Lacalle L.N., Sanchez J.A., Bravo U. (2005) Calculation of the specific cutting coefficients and geometrical aspects in sculptured surface machining // Machining Science and Technology. 9(3). P. 411-436. doi:10.1080/15321790500226614 (in Eng.).

[15] Gouskov A.M., Guskov M.A., Lorong Ph. Panovko G.Ya. (2017) Influence of the clearance face on the condition of chatter self-excitation during turning // Machining and Machinability of Materials. 19(1). P. 17-39. doi:10.1504/IJMMM.2017.10002088 (in Eng.).

[16] Benardos P.G., Mosialos S., Vosniakos G.C. (2002) Prediction of workpiece elastic deflections under cutting forces in turning // Robotics and Computer-Integrated Manufacturing. 22. P. 505-514 (in Eng.).

[17] Brissaud D., Gouskov A., Guibert N., Rech J. (2008) Influence of the ploughing effect on the dynamic behavior of the self-vibratory drilling head // CIRP Annals - Manufacturing Technology. 57(1). P. 385-388. doi:10.1016/j.cirp.2008.03.101 (in Eng.).

[18] Dombovari Z., Barton D.A.W., Wilson R.E., Stepan G. (2011) On the global dynamics of chatter in the orthogonal cutting model // Non-linear Mechanics. 46. P. 330-338. doi:10.1016/j.ijnonlinmec.2010.09.016 (in Eng.).

[19] Kalidasan R., Yatin M., Sarma D.K., Senthilvelan S., Dixit U.S. (2016) An experimental study of cutting forces and temperature in multi-tool turning of grey cast iron // Machining and Machinability of Materials. 18(5/6). P. 540-551. doi:10.1504/IJMMM.2016.078992 (in Eng.).

[20] Gouskov A.M., Guskov M.A., Ding Dyk Tung, Panovko G. (2018) Multi-cutter turning process stability analysis // Vibroengineering Procedia. 17. P. 124-129. https://doi.org/10.21595/vp.2018.19800 (in Eng.).

[21] Ozturk E., Comak A., Budak E. (2016) Tuning of tool dynamics for increased stability of parallel (simultaneous) turning processes // Sound and Vibration. 6(360). P. 17-30. doi:10.1016/j.jsv.2015.09.009 (in Eng.).

[22] Reith M.J., Bachrathy D., Stepan G. (2016) Improving the stability of multi-cutter turning with detuned dynamics // Machining Science and Technology. 20(3). P. 440-459. doi:10.1080/10910344.2016.1191029 (in Eng.).

[23] Gouskov A.M., Voronov S.A., Paris H., Batzer S.A. (2001) Cylindrical Workpiece Turning Using Multiple-Cutting Tool, Proceedings of the Design Technical Conferences and Computers and Information Engineering Conference, September 9-12, 2001. Pittsburgh, Pennsylvania.

[24] Suslov A.G., Dal'skij A.M. (2002) Nauchnye osnovy tekhnologii mashinostroeniya (Scientific bases of technology of mechanical engineering). M.: Mashinostroenie. 684 p. ISBN 5-217-03108-5 (in Rus.).

[25] Chang Kai. (2009) Machining Dynamics. Fundamentals, Applications and Practices. Springer-Verlag, London Limited. ISBN 971-1-84628-368-0

[26] Grasman J. (1987) Asymptotic Methods for Relaxation Oscillations and Applications. Springer – Verlag, New-York Inc. ISBN 0-387-965 13-0

[27] Tihonov A.N., Goncharskij A.V., Stepanov V.V., Yagola A.G. Chislennye metody resheniya nekorrektnyh zadach (Numerical methods for solving ill-posed problems). M.: Nauka, 1990. 232 p.

[28] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[29] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[30] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

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NEW METHODS OF INFORMATION SEARCH. I

Abstract. The paper discusses new methods used to solve the problem of information retrieval of unstructured (text) data. The search for documents is carried out by keywords in natural language used in search engines. The proposed search methods are fundamentally different from the existing methods in time and memory used, as well as in the simplicity of implementing software products based on the developed algorithms. The theorems of sampling a subset satisfying the sum (certificate) *S*, the sum of subset problems, lemmas and algorithms for solving the problem of searching for unstructured data based on a search query with several (two or three) keywords are given. The time and memory required for a search query with two keywords are proportional to $O(n)$. The task of information retrieval with three keywords is reduced to the task of searching for information with two keywords or to the problem of computational geometry. These scientific results are fully based on the materials cited in the USPTO USA, filed on 17.12. 2018 year.

Key words: search, method, algorithm, unstructured information.

Introduction. One and the first fundamental reviews of the tasks of information retrieval and search engines was presented in [1]. To perform a search, many search engines build on the basis of the initial information logical and physical data structures, which are a search index that allows you to implement some given information retrieval model. We define the main types of search queries. It is enough to list them: boolean search, search for relevance, search by pattern (mask), etc. There is no need to decipher each type of search, as it is given in [2]. Currently, several methods of sequential and binary searches are used. The systems that use these keyword search methods include the most common search engines, including such Web search systems as Yandex, Google, AstaVista, Yahoo, etc.

Basic concepts of information retrieval. The task of information retrieval: to find one or more elements in the set, and the desired elements must have a certain property. This property can be absolute or relative. Relative property characterizes in relation to others: for example, the minimum element in the set of numbers.

Definition 1. Let us call the alphabet, a finite set of symbols $A = \{\tau, \alpha_1, \dots, \alpha_k\}$, where τ is a space character, | A | = k, and k> 0 is the number of characters in the alphabet.

Definition 2. A word is a finite sequence of characters from the alphabet, not including the whitespace character τ. We assume that the set of words *W* is always finite.

*Definition*3. A string of length n, we call the sequence of words $D = \{d_1, \dots, d_n, \$\}$, where ∀i, $d_i \in$ W and *$* is a special character that does not belong to the alphabet and denotes the end of the line.

Definition 4. The search query $P = \{p_1, \dots, p_m\}$ is the string consisting of a finite set of words separated by a space character τ. In this case, $| P | = m$ is the length of the query in words, $p_i \in W$, where *i* is the number of the word in the pattern, and *W* is the set of all words. Words in search queries and documents will be called terms (keywords).

Comment. The length of the search query P will always be denoted by the symbol m, and the total length of the source data D, for which the search problem will be solved, is denoted by n.

The main provisions of tabular search methods. Mathematical substantiation of new methods and algorithms for searching unstructured text information by keywords is carried out using a vector-spatial model (each element of the search digital index acts as a coordinate of the vector space), excluding the probabilistic and boolean models.

Thus, the task of information retrieval is reduced to the sum of the subset belonging to the NP class to the complete problem, and the proposed approach allows us to apply the existing criteria for the relevance of documents in vector spaces.

Subset sum problem. Given a set of n numbers and a number S. It is required to determine whether there exists at least one subset whose sum of elements is equal to S.

Currently, information retrieval tasks have been solved for two, three, and four keywords based on tabular m-sums (table m-sum problem, mxn dimension table is specified).

There is a table 2xn and a given number S. You need to find 2 numbers from different lines (one from each line), giving a total of S.

Algorithm A. Brute force. The running time is $O(n^2)$.

Algorithm B. Brute force sorting. Sort the first line, for each element from the second line subtract it from S and look for this difference in the first line. Runtime -O ($n$log$n$). Memory requirement O (n).

There is a table 3xn and a given number S. You need to find 3 numbers from different lines, giving a total of S.

Algorithm A. Brute force. The running time is $O(n^3)$.

Algorithm B. For a single line, find all the differences from S, and for the other two, go through all the options. The running time is $O(n^2)$.

In the future, this material will allow a comparative analysis with the following proposed scientific results.

Open problems finding unstructured textual information. The works [3, 4] are devoted to solving the problem (subset sum problem), in which the search time $T=O(2^{n/2})$ and the required memory $M=O(2^{n/4})$ do not allow the results to be applied in practice. The main disadvantage of tabular methods is the construction of each row of the table by property defined by each keyword. This means that we are obliged to carry out preliminary work on some structuring of input data. In turn, there is an additional problem of splitting a vector space into subspaces according to each keyword.

Therefore, we will change the problem definitions of tabular sums in a more generalized form suitable for the practical search of any information, using the sum of the subset problem. In the future, algorithms for solving these problems can be directly applied to the search for arbitrary unstructured information based on a vector-spatial model and a searchable digital index.

Let us reformulate the formulation of the main problem directly related to the length m of the search query.

The main practical task. Given a set of n numbers and the number S. It is required to find out if there is one or several subsets, each of which consists of m elements, and the sum of these elements is equal to S.

1. A set of n numbers and a number S are given. It is required to find out if there is one or several subsets of two numbers, the sum of whose elements is S and with a running time shorter than $O(nlogn)$.

2. A set of n numbers and a number S are given. It is required to find out if there is one or several subsets of three numbers, the sum of whose elements is S and with a running time shorter than $O(n^2)$.

Now we can move on to the mathematical formulations of the search problems and their solutions.

The main practical task. Given a set of integer (natural) numbers

$(x_1, x_2, \ldots, x_n) \in X^n$ of dimension n. It is required to find out whether there exists a subset X_m of dimension m such that the following conditions are fulfilled:

$$X_m = \{x_i + x_j + \cdots + x_g + x_h = S, i \neq j \neq \cdots \neq g \neq h, x_i, x_j, \cdots, x_g, x_h \in X^n,$$

$$(i, j, \cdots, g, h) \in N = (1,2, \ldots, n), \ \ m \leq n\} \quad (1)$$

Here $x_i, x_j, \cdots, x_g, x_h \in X_m$ with the number of elements $x_i, x_j, \cdots, x_g, x_h$ equals m.

We introduce the following notation: C_n^m -complex, S_n^m-sum of elements of one subset from the set of subsets X_m of the set X^n. In this case, the variable *m* can vary from 0, 1, 2, ..., n. The set of these subsets X_m is determined on the basis of the combination

$$C_n^m = \frac{n!}{m!(n-m)!}. \quad (2)$$

We sort the given vector *x* from the set X^n in descending order and get the sorted set Z^n - the set of vectors *x* whose values of the elements are sorted in descending order, and find the values

$$S_{min}^m = \sum_0^m z_{n-m}, \quad (3)$$

$$S_{max}^m = \sum_0^m z_m . \quad (4)$$

It should be noted that

$$S_{min}^0 = S_{max}^0 = 0, S_{min}^n = S_{max}^n = \sum_1^n x_i = \sum_1^n z_i . \quad (5)$$

We compose the possible ranges of the certificate *S* belonging to a subset of the set of subsets X_m, $S \in [S_{min}^m, S_{max}^m]$. (6)

The solution of the problem of the sum of subsets is based on the following theorems.

Theorem 1. Let certificate S belong to the range $[S_{min}^m, S_{max}^m]$. Then there is a subset X_m,whose sum of elements is equal to *S*.

Proof. The fulfillment of the condition of the theorem (or condition (6)) means that it is necessary to generate all the subsets X_m based on the formula (2) of the set X^n, the sum of the elements of each of them changes from the minimum value S_{min}^m to the maximum value S_{max}^m. This is equivalent to generating all *n*-dimensional vectors from zeros and ones ($e \in E^n$). The above condition allows the enumeration of subsets in order of minimal change in the binary code of the vector *e*. If the *i*-th index of the vector *e* is 1 (one), this means that this element is included in this subset and must be taken into account when calculating the sum of the elements. The definition of *m* indices on which there are units uniquely determines the vector *e* corresponding to one subset of the set of subsets X_m. Then there is a vector *e* such that the sum *S* is calculated on the basis of the scalar product: *S* = (e, x).

Remark1. The dimension of the set X_m easily extends to n if other elements of this set are considered zeros, except for elements with indices $(i, j, \cdots, g, h) \in N$. On the other hand, we can use one of the properties of the combination (2) to reduce the parameter n: $C_n^m = C_{n-1}^{m-1} + C_{n-1}^{m-1}$.

The result obtained can be extended to a set of subsets $X_{n-m}$from the set X^n and introduce the ranges $[S_{min}^{n-m}, S_{max}^{n-m}]$.

Theorem 2. Let certificate *S* belong to the range $[S_{min}^{n-m}, S_{max}^{n-m}]$. Then there exists a subset X_{n-m} whose sum of elements is equal to *S*.

Proof. Based on the equality of combinations $C_n^m = C_n^{n-m}$, we can replace the variable m with the variable *n-m* and the vector *e* from theorem 1 with the vector $\bar{e}$, in which the zeros of the vector *e* are replaced by ones and the ones with zeros. Then there is a vector $\bar{e}$ such that the certificate is calculated on the basis of the scalar product: $S = (\bar{e}, x)$ or $S = S_{min}^n - (e, x)$.

It is easy to find the running time of the algorithm based on theorem 1 using the sorted vector x and the merge method:

$$T = O(C_n^m) < O(2^n). \quad (7)$$

The required memory $M = O(n)$ is necessary to save the vector *e*. Generation of vectors *e* can be made on the basis of the Gray code.

Example 1 of [4]. Consider a vector *x* = (7,3,9,6,2), *S*=11, $C_5^2 = C_5^3 = 10$, $S \in [S_{min}^2, S_{max}^2] = [5,16]$ or $S \in [S_{min}^3, S_{max}^3] = [11,22]$. Then the solutions of the problem of the sum of subsets are the vectors $e = (00101)$, $\bar{e} = (01011)$ and sum $S = (e, x) = 11$ or $S = (\bar{e}, x) = 11$, at $S = 10$, $e = (11000)$.

We turn to solving practical problems.

Task1. It is required to find out if a subset exists

$$X_2 = \{x_i + x_j = S;\ i \neq j;\ x_i, x_j \in X^n;\ i,j \in N\} \quad (8)$$

where $X^n = (x_1, x_2, \dots, x_n)$ is the set of integer (or natural) numbers, N = (1,2, ..., n) is the set of natural numbers.

Task2. It is required to find out if a subset exists

$$X_3=\{x_i+x_j+x_k=S;\ i \neq j \neq k;\ x_i, x_j, x_k \in X^n\ ;\ i,j,k \in N\}. \quad (9)$$

To solve these problems, we introduce the mapping of the set X^n into the set Y^n:

$$y = \tau(S,x) = (S-x)x,\ \forall x \in X^n. \quad (10)$$

Based on the mapping (10), we have that

$$Y^n = \{y_1, y_2, \dots, y_n \leftrightarrow\ \tau(S,x_i) = y_i, x_i \in X^n, i = 1,2, \dots, n\}. \quad (11)$$

Suppose that among the set Y^n there exist elements such that the identity holds:

$$y_i = y_j\ , i \neq j; i,j \in N. \quad (12)$$

Certificate S allows you to find a set of subsets $X_2 = \{x_i, x_j\}$, consisting of pairs of elements of the original set X^n, based on formulas (3) and (4).

Lemma 1. Let certificate S belong to the range $[S^2_{min},\ S^2_{max}]$ and the identity (12) holds for set (11). Then problem1 is solvable.

Proof. The first condition shows the existence of a subset X_2 from theorem1 satisfying the certificate S. To construct vectors e from identity (12), we have $y_i = \tau(S,x_i) = (S-x_i)x_i = x_j x_i$, assuming that $x_j = S - x_i$. On the other hand, $y_j = \tau(S,x_j) = (S-x_j)x_j = x_i x_j$, likewise assuming that $x_i = S - x_j$. In fact, the quantities x_i, x_j are the roots of the quadratic equation $x^2 - Sx + c = 0$. According to the Viet's theorem $c = x_i x_j$. Thus, we get $y_i = y_j = x_i x_j$. The latter means that the fulfillment of identity (12). Then there are elements x_i and x_j such that $x_i+x_j=S$.

We introduce the value

$$S(x_k) = S - x_k,\ \forall x_k \in X^n. \quad (13)$$

Lemma 2a. Let certificate S belong to the range $[S^3_{min},\ S^3_{max}]$ and for some element $x_k \in X^n$ and taking into account formula (13), identity (12) holds for $i \neq j \neq k$; $i,j,k \in N$. Then problem 2 is solvable.

Proof. The first condition shows the existence of a subset X_3 from theorem1 satisfying the certificate S. To construct vectors e from identity (12) with formula (10), we have $\tau(S(x_k),x_i) = (S(x_k)-x_i)x_i = = x_j x_i$, assuming that $S(x_k) - x_i = x_j$. On the other hand, $\tau(S(x_k),x_j) = (S(x_k)-x_j)x_j = x_i x_j$, likewise assuming that $S(x_k) - x_j = x_i$. The latter means that the conditions of Lemma 1 are satisfied when formula (13) is taken into account. Then we have that $x_i+x_j+x_k=S$.

The following lemma is based on computational geometry and is of independent scientific interest. The well-known fact that problem2 was reduced to an equivalent problem of the belonging of three points of one straight line on a plane. However, problem 2 in this formulation has not been solved to date.

In this case, the mapping (10) for the search query with three keywords will be rewritten as:

$$y = \tau(S,x) = (S-x)xx,\ \forall x \in X^n \quad (14)$$

and enter a 3x3 matrix

$$H = \begin{pmatrix} x_i & y_i & 1 \\ x_j & y_j & 1 \\ x_k & y_k & 1 \end{pmatrix}. \quad (15)$$

The coordinates $(x_k\ , y_k)$ on the plane are calculated by the formulas

$$x_k = \big(S - (x_i + x_j)\big), y_k = \Big(S - \big(x_i + x_j\big)\Big)^2 \big(x_i + x_j\big),\ x_i, x_j \in X^n. \quad (16)$$

Lemma 2b. Let the certificate S belong to the range $[S^3_{min},\ S^3_{max}]$ and the determinant Δ of the matrix (15) is zero when considering formulas (16) and some element x_k, defined by the first formula of expression (16), belongs to the set $X^n,\ i \neq j \neq k,\ i,j,k \in N$. Then problem 2 is solvable.

Proof. The first condition shows the existence of a subset X_3 of theorem1 satisfying the certificate *S*. The second condition ensures the construction of vectors *e* based on the application of the well-known result [5] of the belonging of three points $(x_i, y_i), (x_j, y_j), (x_k, y_k)$ of one line lying on the plane (*x*, *y*). Replacing the third coordinate (x_k, y_k) with variables (16) completes the proof of the lemma.

Algorithms search. On the basis of these lemmas, we formulate the search algorithms.

Search algorithm1 for the first task.

Step 1. Input of the initial data: setX^n, *n*, *S*.

Step 2. Formation of the set Y^n on the basis of the map (4).

Step 3. Verification of the identity (5) and the formation of a subset

X_2={ $\tau(S, x_i) - \tau(S, x_j) = 0: i \neq j; x_i, x_j \in X^n$; $i,j \in N$} }.

Step 4. Subset output X_2.

The time of the search algorithm $T=O(n)$, the required memory $M = O(n)$ for the formation of the set Y^n.

For the tabular 2-sum, the exhaustive search time is $T=O(n^2)$ and in the case of sorting $T=O(nlogn)$.

Note2. The maximum number of pairs in the set Y^n is $m=[n/2]$. Thus, the number of pairs in Y^n can vary from 1 to *n/2*.

It should be noted that this algorithm allows you to find all the subsets of X_2 with a small modification.

Example 2. Given a set X^7={2,1,6,4,3,5,3} dimension n=7. It is required to find out whether there exists a subset X_2 ={x_i, x_j}, the sum of these elements from the set X^7 is equal to S = 6. Here $S \in [S^2_{min}, S^2_{max}] = [3,11]$. Initially, on the basis of the mapping $\tau(S, x)$ (map (8)) we translate the set X^7 into the set Y^7={8,5,0,8,9,5,9}. Further, to find the subset X_2, we use the identity (12): $y_i=y_j$, $y_i, y_j \in Y^7$, $i,j \in N$=(1,2,3,4,5,6,7). Then we get X_2=(2,4), X_2=(1,5), X_2=(3,3).

The search algorithm 2a for the second task.

Step 1. Input of the initial data: set X^n, *n*, *S*.

Step2. Calculation of $S(x_k) = S - x_k$ for some element $x_k \in X^n$.

Step3. Formation of the set Y^non the basis of the map (4) with regard to $S(x_k)$.

Step4. The formation of the subset X_3={ $\tau(S(x_k), x_i) - \tau(S(x_k), x_j) = 0$ for $i \neq j \neq k$; $x_i, x_j, x_k \in X^n$; $i, j, k \in N$}.

Step5. Output subsets of X_3.

Remark 2. Given in the search algorithm1 allows us to determine the search time $T=O((n-2m)2m)$. Here, *m* is the number of pairs in the set Y^n, *n*-2*m* is the number of remaining indices without taking into account the used index *k*. It is easy to show that as $m \to \left[\frac{n-1}{2}\right]$ tends, the search time varies with in $O(n) \leq T \leq O((n-2m)2m)$. So, the running time of the algorithm is $T = O\left(\frac{n^2}{2}\right)$.

Search time for tabular 3-sum $T=O(n^2)$.

Example 3. Given the set X^9 ={17,43,38,14,20,10,36,47} of dimension n = 9. It is required to find out whether there exists a subset X_3 ={x_i,x_j,x_k}, the sum of these elements from the set X^9 is equal to S = 100. Here $S \in [S^3_{min}, S^3_{max}] = [51,126]$. First, choose an arbitrary element $x_k = x_6$=10. Find $S(x_k)$ based on the formula (13) $S(x_6)= S - x_6 = 100 - 10 = 90$. Now we use the mapping (10) ($\tau(S, x)$) from the first part of the work and define the set Y^9 for the value $S(x_k)$. Next, apply identity (12): $y_2=y_9$, $S=x_2+x_9+x_6$=43+47+10=100.

Search algorithm 2b for the second task.

Step 1. Input of the initial data: set X^n, *n*, *S*.

Step 2. The formation of the matrix *H*.

Step 3. Check condition $\Delta = |H| = 0$.

Step 4. Checking the ownership of the calculated item

$x_k = (S - (x_i + x_j))$ множеству X^n.

Step 5. Output of subset X_3.

The running time of the algorithm varies within $O(n) \leq T < O(n^2)$, the required memory is $M = O(n)$.

Remark 3. From all combinations of n^2 determinants $|H| \neq 0$ and $|H| = 0$, those for which $\Delta = 0$ are selected and all the elements x_k, belonging to the initial set X^n, are selected from them, the number of such elements is at most n-2 .

Example 4. Given the set X^9 ={2,1,6,4,3,5,3,9,7} of dimension n = 9. It is required to find out whether there exists a subset X_3 ={x_i, x_j, x_k}, the sum of these elements from the set X^9 is equal to S = 15. Here $S \in [S^3_{min}, S^3_{max}] = [6,22]$. If x_2=1, x_6=5, and x_k is determined by the formula (16), x_8 = 9. Then, for these elements, the determinant $\Delta = |H| = 0$, $x_8 \in X^9$, the subset X_3={ x_2, x_6, x_8} is satisfied. It is easy to obtain other subsets, in particular, X_3={ x_1, x_3, x_9}.

The discussion of the results. There are a lot of information retrieval algorithms in the scientific literature based on exponential algorithms from [3,4]. The search time and the required memory are $O(2^{n/2})$ and $O(2^{n/4})$ respectively. The use of these algorithms is difficult due to the finding of $2^{n/2}$ subsets. Tabular search methods are based on the construction of tables. The proposed theorems are virtually independent of the length of the search query and require finding only one subset of the sum of subsets task. Lemmas and examples 2-4 show the solution of the tasks set independently of the combination (7). The developed search algorithms with two and three keywords are the most effective compared to tabular methods. In particular, when m = 1 and m = n-1, the theorems follow the traditional search methods: sequential search and pattern matching (mask search). Theorems 1 and 2 allow us to construct a whole family of algorithms for sampling unstructured data for a “short” search query with m keywords and a “long” search query with n-m keywords.

Conclusion. The analysis shows that new methods of information retrieval based on a search query with several keywords significantly reduce the search time for unstructured data, as well as reduce the hardware requirements for the power of computers, servers and other computing devices used. The developed mathematical theory of information retrieval of unstructured data eliminates the need to use arrays, trees, index arrays, index trees, and other well-known information retrieval algorithms that do not drastically improve the search time.

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АҚПАРАТТЫҚ ІЗДЕУДІҢ ЖАҢА ӘДІСТЕРІ. I

Аннотация. Мақалада құрылымдық емес (мәтіндік) деректерді іздеудің проблемасын шешу үшін қолданылатын жаңа әдістер талқыланды. Құжаттарды іздестіру іздеу жүйелерінде қолданылатын табиғи тілдегі негізгі сөздермен жүзеге асырылады. Ұсынылған іздеу әдістері қолданыстағы әдістерден уақыт пен жадыдан, сондай-ақ дамыған алгоритмдер негізінде бағдарламалық өнімдерді енгізудің қарапайымдылығымен түбегейлі ерекшеленеді. Бірнеше (екі немесе үш) кілт сөзбен іздеу сұранысы негізінде құрылымдық емес деректерді іздестіру мәселесін шешу үшін S (сомасы) сомасын (сертификатын) қанағаттандыратын шағын жиынтықтаудың теоремалары келтірілген. Екі кілтік сөзбен іздеу сұрауы үшін қажетті уақыт пен жад O (n) үшін пропорционалды. Ақпаратты үш кілт сөзбен іздеу қызметі екі кілт сөзбен немесе есептік геометрия мәселесіне ақпарат іздеу тапсырмасына дейін азаяды. Бұл ғылыми нәтижелер 17.12-де жарияланған АҚШ патенттік өтінімінде келтірілген материалдарға негізделген. 2018 жылы.

Түйін сөздер: іздеу, әдіс, алгоритм, құрылымдық емес ақпарат.

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НОВЫЕ МЕТОДЫ ИНФОРМАЦИОННОГО ПОИСКА. I

Абстракт. В работе рассмотрены новые методы, применяемые для решения задачи информационного поиска неструктурированных (текстовых) данных. Поиск документов осуществляется по ключевым словам

на естественном языке, применяемых в поисковых машинах. Предлагаемые методы поиска принципиально отличаются от существующих методов по времени и используемой памяти, а также - простоте реализации программных продуктов на основе разработанных алгоритмов. Приведены теоремы выборки подмножества, удовлетворяющего сумме (сертификату) S, задачи о сумме подмножеств, леммы и алгоритмы решения задачи поиска неструктурированных данных на основе поискового запроса с несколькими (двумя либо тремя) ключевыми словами. Время и требуемая память для поискового запроса с двумя ключевыми словами пропорциональны $O(n)$. Задача информационного поиска с тремя ключевыми словами сведена к задаче поиска информации с двумя ключевыми словами либо к задаче вычислительной геометрии. Эти научные результаты полностью опираются на материалы, приведенные в заявке на патент USPTO США, поданной 17.12. 2018 года.

Ключевые слова: поиск, метод, алгоритм, неструктурированная информация.

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REFERENCES

[1] Van Rijsbergen C.J. "Information Retrieval". Dept. of Computer Science. University of Glasgow, 1979 (in Eng.).

[2] Adamansky A. Overview of methods and algorithms for full-text search. Novosibirsk: Novosibirsk State University, 2018. 26 p. (in Rus.).

[3] Horowitz E., Sanni S. Computing Partitions with the Application to the Knapsack Problem // Journal of the ACM (JACM), 1974, T21. P. 277-292 (in Eng.).

[4] Schroeppel R., Shamir A. A $T=O(2^{n/2})$, $S = O(2^{n/4})$ Algorithm for Certain NP-Complete Problem // SIAM Journal on Computing. 1981. Vol. 10, N 3. P. 456-464 (in Eng.).

[5] Korn A., Korn M. Mathematical Handbook. New York: McGraw-Hill Company, 1968. 832 p.

[6] Lifshiz Y. Exact algorithms and open problems // yura@logic.pdmi.ras.ru (in Rus.).

[7] Akhtanova S.S. Algorithms of Data Search // Modern Technologies. 2007. N 3. P. 11-17.

[8] Simakov V.S., Tolkachev D.M. Methods and algorithms for finding information on the Internet. M.: Globus, 2017. 332 p. (in Rus.).

[9] Knut D. The art of programming. Sort and search. Vol. 3. M.: Williams, 2000. 844 p. (in Rus.).

[10] McConnell J. Analysis of Algorithms. M.: Tekhnosfera, 2002. 304 p. (in Eng.).

[11] Urvacheva V.A. Review of information retrieval methods // Bulletin TI them. A. P. Chekhov. 2016. P. 1-7 (in Rus.).

[12] Sinchev B., Sinchev A.B., Akzhanova Z.A. Search for unstructured information // Application for a patent in the USPTO USA dated December 17, 2018. 70 p. (in Eng.).

[13] Sinchev B., Mukhanova A.M. **(2018)** The design of unique mechanisms and machines. II //

News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018. Vol. 5, N 431. P. 210-217. https://doi.org/10.32014/2018.2518-170X.27 ISSN 2518-170X(Online), ISSN 2224-5278(Print).

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