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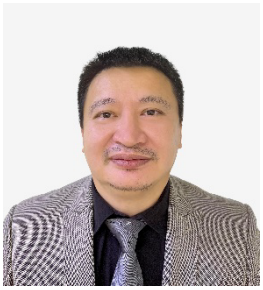

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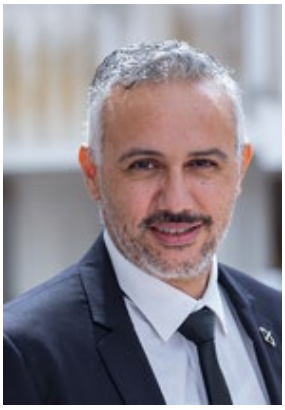

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Section "Machine building and automobile transport"

Dear Colleagues,

on the occasion of the International scientific and technical conference “Innovative development of resource-saving technologies and sustainable use of natural resources”, I wish you a collegial greeting and warm congratulations for all the accomplishments in your activity.

Eaven in this dificult periods of war it is a great pleasure, for me and my colleagues, that the University of Petrosani, in this year when we celebrate 75 th Anniversary, are co-organizer of your well known and appreciated conference.

The Conference became more and more important for both our universities due to the quality of scientific papers and of course due to the Scientific committee of the conference which includes scholars and manufacturers from more and more countries of Europe, Asia, Australia and Africa. A lot of specialists from Poland, Bahrain, Zambia, Spain, Vietnam, Republic of Azerbaijan, Republic of Guinée, and of course from Romania and Ukraine, and having an orientation of scientific research towards the top problems of the theory and practice of economic and social life are presented.

Every year makes the National University of Water and Environmental Engineering a more powerful center of scientific and cultural irradiation, well integrated in the circuit of international cooperation.

I wish you health, luck and happiness being convinced that the collaborative relations between our universities will rise in future, in a Europe in peace and prosperity.

Sincerely yours,
Professor Ph.D.Eng. *Sorin Mihai RADU*
Rector of the University of Petrosani, Romania

Dear friends, colleagues, organizers and attendees of the VI International Scientific and Technical Conference “Innovative Development of Resource Saving Technologies and Rational Use of Natural Resources”!

This is our second conference held in conditions of the full-scale aggression of the Russian Federation which is pursuing a policy of genocide against the Ukrainian people trying to destroy our culture and science. It is destroying our universities, schools, hospitals, and cultural heritage sites.

The University helps our army in every possible way. Volunteers maintain contacts with military units and try to solve their humanitarian problems. Some of our colleagues have joined the Defense Forces of Ukraine and are now participating in military operations.

The University is constantly improving. The educational process at the University is provided by 774 faculty members including 69 Doctors of Sciences, 82 Professors, 364 PhDs, 259 Associate Professors.

The university is an active participant in many international programs. Every year, our senior students and academic staff do an internship under the Erasmus+, Fulbright Program, and the Fédération Échange France-Ukraine (Exchange Federation France-Ukraine). A while ago, a team of the NUWEE scientists took part in the I World Science Championship in Dubai where they became the bronze award winners in engineering.

We are grateful to our colleagues from the University of Petrosani, to Rector of the University Professor Sorin-Mihai RADU and to all those involved in preparing and holding the conference.

The international status of the conference is confirmed by the Scientific Committee, comprising top scientists from 48 countries of Europe, Asia, Africa, America and Australia. They believe in Ukrainian science and support it in these difficult times.

Three sections of the conference present more than 60 abstracts from 33 scientific institutions and enterprises of 9 countries.

We are pleased to welcome participants from Ukraine, Romania, Poland, Bahrain, Zambia, Spain, Vietnam, Azerbaijan, the Republic of Guinea, and other countries.

I am confident that the conference will be effective and fruitful and yield good scientific results. Just believe in yourself and your dreams will come true.

GLORY TO UKRAINE!

Sincerely yours,
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GENERAL CONSIDERATIONS REGARDING THE USE OF FOSSIL FUEL BASED ENERGY

Introduction

Mineral resources (such as: fossil fuels, metals, building materials and other minerals are essential to ensure the prosperity and welfare of human society.

The most acute problem in terms of energy resources is the pace and how they are exploited and used. Based on the concept of sustainable development of human society, the current consumptions must be analyzed and predictions must be made on the trends in use of fossil energetic resources [1]. In the paper, although we must refer to energetic resources in the context of globalization, there are presented a number of references to common guidelines established in the perspective of 2020-2050 [2].

1. Demand of energetic resources

The main causes that lead to an increase in demand for energetic resources are represented by continuous population growth (in the twentieth century the global population has increased 4 times than in the nineteenth century) and by the rising of living standards.

In terms of energetic resources, for the same period, fossil fuel consumption has increased by 12 times [1].

At EU level, in a globalized economy, there is a more pronounced impact on economic, social or environmental levels generated by global changes in terms of energetic resources [3]. Given current trends, almost all forecasts and scenarios are considering a growing demand for energetic resources.

The data presented in the paper on traditional energetic resources (current reserves, operating rate, duration of operation, etc.) are based on a scenario regarding population growth up to 11 billions until 2100 [1].

The most worrying situation is that of population growth on the African continent, where according to this scenario, the population would grow by approx. 4 times in the next 85 years, reaching approximately 4.185 billion inhabitants. [2]

Beyond the obvious increasing demand for energetic resources due to population growth, we must bear in mind that African countries are classified as either as developing countries or third world countries, which means that as they will economically develop the demand of energetic resources per capita will expand at least proportionally (driven by the increase of living standards) [1].

2. Classic energetic resources, current consumption and trends

This includes fossil fuels such as coal, oil, natural gas, oil shale, tar sands and shale gas. According to the latest data available, globally, in 2012, fossil fuels provided over 78.9% of the total energy demand, as can be seen from figure 1 [4].

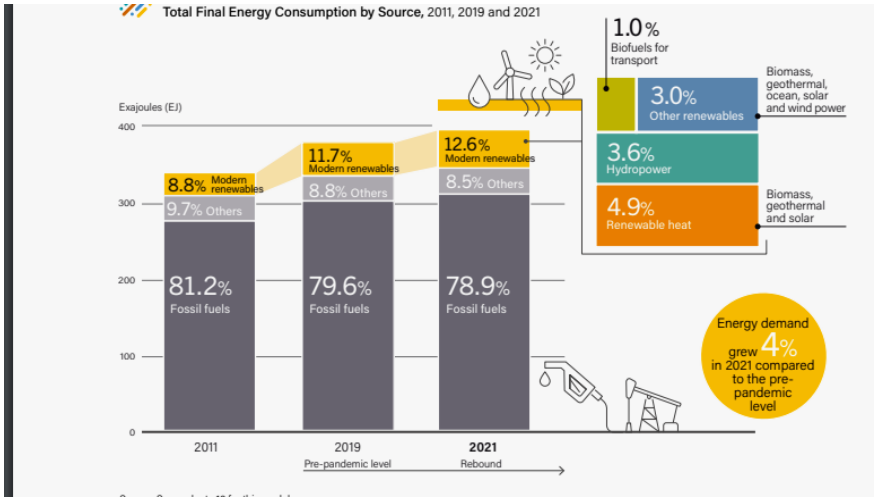

Fig. 1. Total energy consumption by source [5]

Current scenarios developed by specialists on energy consumption shows a decrease in the share of fossil fuels in participating in the production of only a few percent. In this context, we can expect an environmental problems emphasize caused by increased CO_2 emissions from the combustion of additional natural gas and oil.

Coal - It is used as a solid fuel to produce electricity and heat. Currently, world production amounts to approx. 8 billion tons [6] and is expected to increase (up to 9,05 billion tons) by 2030. The percentage of coal used for energy production varies from one country to another (for example in USA over 40% of the energy generated is based on burning coal while the EU average share is below 15%).

The total recoverable coal reserves are estimated at about 860 billion tones which at the current consumption rate would reach (theoretically) for another 112 years compared to an earlier estimated 147 years (in 2007 by British Petroleum) [7].

Crude oil - Also plays an important role in energy production (electricity and heat) and in transport (on land, sea and in air).

The top three oil producing countries are: Russia, Saudi Arabia and USA. About 80% of the world's readily accessible reserves are in the Middle East (62,5% belonging to five countries: Saudi Arabia, UAE, Iraq, Qatar and Kuwait) [1].

Much of total global oil consists of unconventional resources (conventional oil reserves represent 30% of the total while tar sands represent 30%, heavy oil 15% and extra heavy oil 25%) [8].

Given those presented in paragraph 1, the estimation that oil reserves would be sufficient for another 120 years is extremely optimistic (or deeply flawed). The scenarios that take into account

the elements mentioned are more pessimistic and shows that conventional and unconventional oil reserves (proven ones) would last for a period between 40 and 60 years [1].

Natural Gas - The third category of traditional energetic resources is represented by natural gas. They consist of gaseous hydrocarbons, predominantly being the methane. For an equivalent amount of heat the emission of carbon dioxide is 30% lower than in the case of burning oil and about 45% lower than in the case of coal combustion [9].

The natural gas global reserves are difficult to assess, because of shale gas (the alleged deposits being under exploration in most of the world).

Based on a 2015 estimated consumption of 3.4 trillion cubic meters of gas per year, the estimated total reserve of economically recoverable reserve would be enough for 250 years, but an annual growth in consumption by 2-3% would result in a shortening of the this period down to 80-100 years [1].

However the considerations regarding the periods of time for which gas will be available should be treated with caution due to insufficient available information on existing shale gas volumes. Since 2000, shale gas has become an important source of natural gas in the US and Canada, and as a result of the successes other countries started exploration works on shale gas reserves.

Conclusions

Given that, as shown, for the near future a significant decrease in the share of fossil fuels in the global energy balance is not expected, it is hard to speak of a rationalization of their exploitation. Basically if we take into account the projected population growth and energy demand per capita it can be concluded that the pace of exploitation of fossil fuels will be growing, at least until 2030.

This can be translated simply by a decrease in the current periods for which proven reserves were estimated to be sufficient.

Although the application of new technologies, more efficient, involve higher costs, the increasing demand and falling supply will lead to an increase in value of the production and such technologies will become viable.

The current alternative energy sources contribute to global energy balance by little more than 20%. For a sustainable management of classical energetic resources these sources should contribute more to the global energy balance. However, the estimates for the next period show a relatively modest growth.

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GEOTECHNICAL PROPERTIES OF OVERBURDEN LOW-COHESION ROCKS FORMED DURING THE DEVELOPMENT OF IRON QUARTZITE DEPOSITS

Miners and geotechnical engineers have some positive experience in utilizing overburden accumulated during the development of mineral quarries [1-3]. Thus, it has been proven that it is economically and environmentally feasible to use overburden of low-cohesion rocks as materials for artificial massifs, including the foundations of structures, such as layer-compacted sand or soil cushions, but the geotechnical aspects of their use in cushions have not been sufficiently studied.

Therefore, a rather urgent task was set - to conduct comprehensive laboratory and field studies of the physical and mechanical properties of compacted overburden and low-cohesion rocks and experimentally obtain statistical data on the scatter of these characteristics, while checking the compliance of the existing regulatory approach to quality control of soil compaction during the construction of artificial foundations with modern mechanisms and investigating the impact of technological parameters and their variability on the characteristics of compacted soil, etc.

In particular, the study determined the optimal parameters for rolling quaternary quartz deposits (three characteristic types of overburden of the Yeristovo and Lavrykovo iron quartzite deposits): fine, homogeneous sand; a mixture of fine, homogeneous sand with sandy loam; and medium-sized, homogeneous sand. Also, geotechnical quality control of compaction (rolling) of overburden sands of the 4-6 m thick pillow layers of 190 ha for the facilities of the Vorskla Steel direct reduction iron and steel plant with a capacity of 3 million tons of slabs per year near the town of Horishni Plavni, Poltava region, was carried out.

Since the area was flooded, drainage trenches with a cross section of 1,0×1,5 m and a spacing of 3 m were arranged to strengthen the foundation, which were filled with granite rubble. The embankment material was delivered to the site by dump trucks from the quarries. It was leveled to a horizontal level using bulldozers or graders. The initial thickness of the dumped overburden layer was mostly 0,45-0,5 meters. The next step was to compact the soil with rollers in a vibratory mode - two passes in one trail, with a low speed of the compaction mechanisms (2-3 km/h). In this mode, soil particles occupy a more compact position in space, and the artificial massif becomes more

homogeneous in density. The next three passes in a row were performed in the vibration mode, but with a higher frequency and amplitude. Then, if necessary, the soil was moistened to the optimum moisture content using a watering machine and a technological break was organized for 2-3 hours to ensure that the moisture was evenly distributed throughout the entire layer. The next mode of rolling the cushion layer was used both vibration and static. The total number of passes of the sealing mechanism in one trace ranged from 5 to 12.

During the geotechnical quality control of the soil compaction of the cushion, the following was recorded: the initial thickness of each layer of the dumped rock; the decrease in its surface under the roller; the initial density of the soil skeleton within the layer after its dumping and leveling; the number of passes of the roller in one trace; the geometric dimensions of the working body and its operation mode.

The quality of soil compaction of each layer of the cushion was monitored by taking 3 rock samples for every 300 m^2 in rings of 40 cm^2 and 140 cm^3 from the pits. In the laboratory, the physical properties and strength and deformability characteristics of the compacted soil (angle of internal friction, specific adhesion, and deformation modulus) were determined using standard methods. The results of these studies were grouped according to the technological parameters of soil compaction and the types of test overburden sands.

Based on the analysis of the results of field and laboratory studies with a sample size of 50 to 3000 random variables (RV), reliable statistical data on the variability of the values of the characteristics of compacted overburden with low cohesion on the variability of technological parameters of pillow arrangement were obtained, which allowed us to make the following generalizations.

Waste generated during open-pit mining in the mining and processing industry, in particular overburden, should be used as a material for geotechnical structures.

The standard laboratory Proctor test does not provide the maximum soil skeleton density and optimum moisture content that meet the capabilities of modern heavy compactors, especially in the vibration mode of their operation. More accurate data is obtained using a modified Proctor test. The optimal compaction parameters for specific rocks and mechanisms should be determined by the values of the shock pulse, which are close to the technical characteristics of the seals.

The compaction performance of overburden with low cohesion depends significantly on the proximity of its moisture content to its optimum value, the thickness of the filled layer, the number of passes of the roller and its operation mode, which should be determined for each type of seal by means of experimental seals. When arranging the leveling layer of cushions, it is not advisable to use the vibration mode at high groundwater levels. The vibration mode allows compacting low-cohesive rocks in layers of 40-60 sm thick to the standard values: the first two passes should be per-

formed with a low frequency and amplitude of oscillations at the lowest possible speed, and for subsequent passes, the frequency and amplitude should be increased.

With a decrease in the coefficients of variation of the thickness of the subsoil layer and soil moisture in it, the variability of the soil skeleton density decreases. The most significant influence on this indicator is the type of soil and the content of impurities in it. Therefore, statistical samples should be formed taking into account both the parameters of the mechanisms and the particle size distribution of the soil and the content of impurities in it.

The geotechnical properties of the compacted soil mixture are not worse than those of homogeneous compacted soils, although there is an increase in the scatter of their values, and random values of the soil skeleton density of a poorly mixed mixture are characterized by the bimodality of the experimental graph of their distribution. The technological mixing of different types of soils and the vibration mode significantly affect the specific cohesion of compacted soils and slightly affect the angle of internal friction; the value of the deformation modulus of the compacted material depends on the density of the soil skeleton and the pressure interval in compression experiments.

For the analytical description of the experimental distribution of the physical characteristics of compacted soils, it is advisable to use the normal distribution law, and for the density of the soil skeleton of compacted mixtures - the polynomial exponential law. In this case, the coefficient of variation of the soil skeleton density ranged from 2-4,4%, its moisture content - 23-36%, and the soil specific gravity - 4-4,6%.

The deformation modulus of compacted soils and their mixtures is best described by a logarithmic normal distribution law. The coefficient of variation of the deformation modulus is 33-57%. The angle of internal friction φ and the specific c cohesion of compacted soils and their mixtures are random vectors and are best described by a normal and logarithmically normal distribution law, respectively. The coefficient of variation of the internal friction angle was 11%, and the specific adhesion was 25%. The values of the specific resistance to penetration of compacted soil are best approximated by an exponential distribution law. The coefficient of variation of the values of the specific penetration resistance was 57%.

The strength of compacted soil within the cushion is greater in the horizontal direction than in the vertical direction. Artificial soil massifs are characterized by the so-called induced anisotropy of their mechanical characteristics.

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BACTERIA AND ENZYMES IN THE FIGHT AGAINST PLASTICS

Evolutionary processes occur in nature all the time. Due to the increasing number of plastics in nature, it has not remained indifferent to such a common and easily accessible food source. The simpler the organism and the shorter it lives, the faster changes can occur in it. Bacteria were the first to adapt to the new reality.

In 2016, the bacterium *Ideonella sakaiensis* was identified at a waste disposal center in Sakai, Japan. What sets it apart is that it can produce an enzyme that breaks down polyethylene terephthalate (PET) into monomers and draws energy from it. Of course, such a discovery did not go unnoticed and research began. According to scientists, its 201-F6 *b* strain produces the most effective enzymes. Research has shown that polyethylene terephthalate decomposes into a material that has the properties of crude oil, making it suitable for re-production of plastics. This research was conducted by a team led by prof. Alain Marta from the University of Toulouse, head of the scientific team at Carbios [1]. In laboratory conditions, depolymerization using this method at 72°C lasts 10 hours and is 90% effective. This enzyme was called PET-ase. There are plans to produce it using mushrooms. Producing plastic using this method generates only 4% of the costs, if the base amount is the price of producing plastic directly from crude oil. Unfortunately, this does not mean that recycled plastic will be cheaper, because a lot of money goes into the process of separating PET from the waste stream, cleaning it, drying it, grinding it and heating it.

Another team of scientists also decided to study this unusual bacterium and, above all, the enzyme it produces. Researchers from the University of Portsmouth, US Department of Energy's National Renewable Energy Laboratory (NREL) and the University of Campinas in Brazil decided to study the structure of the enzyme using the powerful UK's Diamond Light Source. After analysis, the structure of PET-ase was slightly changed to compare it with another enzyme. This second enzyme is responsible for the breakdown of cutin, a naturally occurring polymer that can be found in the protective coating of plants. Unexpectedly, it turned out that the new enzyme had a 20% greater ability to degrade PET. Additionally, tests have shown its effectiveness in degrading PEF material.

Another name for this material is poly(ethylene 2,5-furanedicarboxylate) and it is presented as the successor to PET. Its production is based solely on plant raw materials, specifically biomass containing carbohydrates, such as cereals, sugar cane, and agricultural residues. This material is much more resistant to high temperatures, has three times better barrier properties in terms of carbon dioxide penetration, and in terms of oxygen, this parameter is six times better compared to

PET. It will probably gradually replace existing plastics from the beverage sector, which will involve developing technologies for its recycling.

Returning to the modified enzyme, observations suggest that further modifications can be made to it. Current efforts are aimed at obtaining a variant that is stable and active at temperatures higher than 70°C. The current enzyme degrades at higher temperatures, but at these temperatures PET takes on a rubbery structure and could decompose 10 to 100 times faster. Recycling would then involve throwing used bottles into a reactor with hot water and an enzyme to soon obtain the monomers necessary to produce new products. A team from Northwestern University also conducted research on improving the enzyme's operation. Their idea was to build polymers that would encapsulate the enzyme to protect its structure. It could then function outside living cells and in the laboratory at higher temperatures.

Scientists noticed that the *Rhodococcus ruber* bacteria forms a biofilm layer on plastic particles in seawater, so there was a suspicion that it did it for a reason. Scientists from the Royal Netherlands Institute for Sea Research, NIOZ, checked whether it decomposes plastic. For this purpose, plastic containing C-13 carbon was added to sea water with *Rhodococcus ruber* bacteria. This isotope is much rarer in nature than the common C-12. Everything was illuminated with UV rays. After some time, carbon dioxide appeared on the surface of the tank. Its analysis showed that it contained the previously mentioned rare isotope. Therefore, it was found that it must have been freed from the plastic thanks to bacteria that began to decompose it. Unfortunately, the rate of decomposition is low. Bacteria are most likely capable of breaking down 1% of available plastic per year. Current observations prove that plastic is disappearing from the oceans, there is less of it than there should be, despite the fact that it should not be there at all. This may indicate the activity of bacteria such as *Rhodococcus ruber* or other species of microorganisms, and perhaps even complex organisms [2]. This gives hope for reducing the problem of plastic in the environment, but also for effective recycling without harm to the environment. Since it was possible to modify the enzyme, perhaps in the future the plastic-metabolizing bacteria themselves can be improved [3, 4].

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HARNESSING THE POWER OF ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE RESOURCE CONSERVATION

Abstract

The sustainable use of natural resources is a pressing global concern, particularly in the context of building and housing sectors, which significantly contribute to resource consumption and environmental impact. As the world population continues to grow and urbanization intensifies, there is an urgent need to adopt innovative approaches to ensure the responsible and efficient utilization of resources. Artificial Intelligence (AI) has emerged as a powerful tool that holds immense potential in addressing the sustainability challenges faced by the construction industry.

This paper explores the benefits of AI in promoting sustainable resource management in building and housing sectors. It highlights how AI technologies can optimize the use of natural resources throughout the lifecycle of construction projects, from design and planning to operation and maintenance. By leveraging AI techniques such as machine learning, data analytics, and optimization algorithms, various aspects of sustainable resource management can be addressed effectively.

One key area where AI can make a significant impact is in the optimization of energy consumption in buildings. AI algorithms can analyze real-time data from sensors and devices within a building, enabling intelligent control of heating, ventilation, and air conditioning (HVAC) systems, lighting, and other energy-consuming components. Through continuous monitoring and adaptive learning, AI can dynamically adjust energy usage based on occupancy patterns, weather conditions, and other factors, resulting in substantial energy savings and reduced carbon emissions.

Furthermore, AI can facilitate the efficient utilization of building materials. By analyzing historical data, AI algorithms can predict material demand, optimize inventory management, and suggest alternative sustainable materials with similar or improved properties. This can help reduce waste, minimize resource extraction, and promote the use of eco-friendly construction materials.

In addition to energy and material optimization, AI can enhance water management in buildings. Through the integration of data from smart meters, weather forecasts, and occupancy patterns, AI algorithms can optimize water usage, detect leaks, and enable predictive maintenance of water systems. This proactive approach not only conserves water resources but also reduces costs associated with water consumption and repairs.

Moreover, AI can contribute to improved waste management practices in the construction industry. By analyzing data on waste generation, AI algorithms can identify patterns and recommend strategies for waste reduction, recycling, and responsible disposal. This can help minimize the environmental impact of construction activities and promote a circular economy approach.

The paper also discusses the challenges and considerations of implementing AI for sustainable resource management, including data availability, privacy concerns, and the need for interdisciplinary collaborations. It emphasizes the importance of regulatory frameworks, industry standards, and stakeholder engagement in harnessing the full potential of AI for sustainable building practices.

In conclusion, AI presents a transformative opportunity to achieve sustainable use of natural resources in the building and housing sectors. By leveraging AI technologies, stakeholders can opti-

mize energy consumption, enhance material utilization, improve water management, and implement effective waste reduction strategies. The integration of AI into sustainable building practices can contribute to the creation of greener, more resource-efficient buildings and pave the way for a sustainable future.

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THE BIOCHAR APPLICATION AS AMENDMENTS IN TECHNOSOLS

Soil degradation processes, as a result of anthropogenic activity, exceeding the natural soil formation rates, are urgent problems of our time. Among the major soil degradation processes are accelerated erosion, depletion of the soil organic carbon pool, loss of soil fertility and elemental imbalance, acidification and salinization (Lal, 2015). In industrially developed regions, degradation occurs especially quickly, since during the cycles of mining and production a large amount of land is formed, unsuitable for farming. The disadvantage of such soils is not only loss of fertility, but also pollution by heavy metals and other industrial wastes. A direct implication of the imbalance between agricultural soil loss and erosion is that, given time, continued soil loss will become a critical problem for global agricultural production (Pimentel, 2006). Soil degradation trends can be reversed by conversion to a restorative land use and adoption of recommended management practices. Improving soil quality can reduce risks of physical, chemical, biological and ecological soil degradation. Techniques of restoring soil quality include conservation agriculture, integrated nutrient management, and continuous vegetative cover such as residue mulch and cover cropping, and controlled grazing at appropriate stocking rates. The strategy is to produce “more from less” by reducing losses and increasing soil, water, and nutrient use efficiency (Labreuche et al., 2011. Sustainable intensification, producing more from less by reducing losses and increasing the use efficiency, is attainable through improvement of soil quality including chemical quality or soil fertility. Use of organic amendments, by recycling organic by-products is a useful strategy to enhance soil fertility and improve structural stability or aggregates (Laird, 2007). Use of biochar and biochar-compost mixtures from different alternative organic sources can be proposed as an option for improving soil fertility, restoring degraded land, and mitigating the emissions of greenhouse gasses associated with agriculture.

Biochar application could be a feasible alternative to remediate the degraded soils and improve their productivity potential in the long-term period (Verheijen, 2009). In the conventional sense, the term biochar means biomass that has undergone pyrolysis in an oxygen-free environment. Owing to

its immanent properties, the biochar is regarded as soil amendment for sustained carbon sequestration and concurrent improvement of soil functions. In the presence of biochar in the soil mixture, its contribution to the physical nature of the system may be significant, influencing depth, texture, structure, porosity and consistency through changing the bulk surface area, pore-size distribution, particle-size distribution, density and packing. Biochar's effect on soil physical properties may then have a direct impact upon plant growth because the penetration depth and availability of air and water within the root zone is determined largely by the physical make-up of soil horizons (Hardie et al., 2014). Each biochar made with a particular feedstock and process combination presents a unique mixture of phases and microenvironments that gives rise to a unique set of chemical properties. The molecular structure of biochars shows a high degree of chemical and microbial stability. A feature of most biochars is their highly porous structure and large surface area, which can provide a shelter for beneficial soil microorganisms and affects the binding of important nutritional cations and anions. This binding can increase the availability of macronutrients such as N and P. Moreover, the biochar application can lead to alkalinization of soil pH, increased conductivity and capacity of cation exchange (Kameyama et al., 2012). The application of biochar to marginal soils can contribute to a good physical, chemical and biological environment of the soil, and these positive changes influence growth and yield (Ippolito, 2011; Pandian et al., 2016). Application of biochar for remediation of contaminated soils can provide a new solution to the soil pollution problem. Due to a large surface area, biochar has a high ability to adsorb heavy metals and organic pollutants. It can potentially be used to reduce the bioavailability and leachability of heavy metals and organic pollutants in soils through adsorption and other physicochemical reactions. Biochar is typically an alkaline material which can increase soil pH and contribute to stabilization of heavy metals (Paz-Ferreiro et al., 2014). Despite the great interest in the use of biochar in agriculture and for remediation, its current use is still limited. In terms of market development, if biochar can be used as a soil amendment to improve soil quality and to increase crop production, this will increase its appeal. In this regard, an obvious positive attribute of biochar is its value, supplied indirectly by improving soil quality, with consequent improvement in the efficiency of fertilizer use. A lack of long-term, well-designed field studies on the efficacy of biochar and biochar- mixtures on different soil types and agro-climatic zones are limiting current understanding of biochar's potential to enhance crop production and mitigate climate change. Results of some researchers showed benefit of biochar application to soils on crop productivity in average 10%. The greatest positive effects with regard to soil analyses were seen in acidic (14%) and neutral pH soils (13%), and in soils with a coarse (10%) or medium texture (13%) (Jeffery, 2011; Biederman & Harpole, 2013). The results obtained in our pot experiments are slightly higher (by 10-15%) than the published data. However, the difference in

the results of field and pot experiments almost always takes place. In addition, it is necessary to take into account the genetic characteristics of plants.

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STUDY OF TOXICANTS IMPACT ON THE ECOSPHERE

Increase in the level of ionising radiation, the source of which are radio-active substances, such as 235U, 232Th, 90Sr, 137Cs, as a result of spontaneous transformation of which can arise *a* and *b* particles, neutrons, g-rays, has a toxic effect on humans, causing genetic changes. As it is known the state of the environment, pollution of the atmosphere, water, soil, quality of products consumed by the population are the main environmental factors affecting the health of the population.

Over the last decades it has been revealed that natural substances have the same and sometimes even greater impact on the biosphere than anthropogenic substances, which are not always envi-

ronmentally safe. The peculiarity of anthropogenic impact on nature is that it produces, highly toxic for all living things, products.

The emergence of toxic pollution can also be associated with the accumulation of natural substances (eg: heavy metals - lead, chromium, cadmium, etc.), and with the production of new substances (pesticides, etc.), as well as with the content of radioactive elements.

Therefore, it is very important early detection of toxic effect of chemical products contained in certain natural materials on the environment.

This should take into account the observance of the three main tasks of ecology, the solution of which depends on the preservation of habitat, assessment of the impact on the environment of toxic substances and prediction of their further behaviour, distribution and transformation of the environment.

Observance of the basic principles determines the preservation of the environment in its pristine form.

Taking into account the fact of wide use of natural aluminosilicates, in particular bentonite clays, in industry and household, it was of scientific and practical interest to study the distribution of radio-active elements in them.

A number of bentonite clays selected from different deposits of the Azerbaijan Republic have been analysed. Volume activity of 226 Ra isotope was measured on gamma-spectrometer with HPGe-detector (Canberra), activity of uranium isotopes (234U, 235U and 238U) was measured on Alpha Analyst Alpha Spectrometer (Canberra), and activity of isotopes in solution during joint sorption of uranium and radium isotopes TriCarb 3100 was determined in liquid scintillation counter TR (Perkin Elmer).

As a result of the research it was established that all of them are radioactive to some extent (70,0-140 Bq/kg|) and contain radioactive elements 235U, 232Th, 226Ra and others. It has been established that the radioactivity of bentonite deposits is territorially closely related to the location.

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DEVELOPMENT OF AN APPROACH TO THE EFFECTIVE RESTORATION OF THE EARTH'S SURFACE DISTURBED BY MINING OPERATIONS

The mining industry in Ukraine, despite a significant contribution to budget revenues, has created a serious technogenic burden on the environment and population in mining regions. The greatest damage in terms of scale is caused by the complex iron ore mining using open-pit and underground methods, because mining enterprises of this industry annually extract about 160 million tons of iron ores from the subsoil, and the volumes of mining waste generated reaches 79% of all solid industrial waste in Ukraine [1,2]. Mining and processing of iron ores leads to significant earth's surface disturbances, while significant land areas are allocated for quarrying and storage of large-tonnage mining waste (dumps, tailing dams). At the same time, underground mining of iron ores without backfilling the mined-out space leads to the earth's surface subsidence with subsequent formation of large-scale failure zones. In terms of land area occupied by the mining industry, Dnipropetrovsk Oblast is the leader (23,57 thousand hectares or 44,7% in Ukraine), where mining enterprises of the Kryvyi Rih Iron-ore Basin are of primary importance. The total earth's surface subsidence area in oblast is estimated at 15,6 thousand hectares [3].

To restore the earth's surface state, mining enterprises usually choose simple and relatively cheap reclamation options – the usual filling of technogenic cavities (quarries and failures) with waste rocks from quarries and mines with the subsequent application of a fertile soil layer. This is feasible if there are large reserves of waste rocks near the quarries. However, the formation of a bulky mass does not guarantee long-term geomechanical earth's surface stability due to its porosity and high filtration properties, which leads to subsidence and instability of the surface. It is therefore risky to use restored earth's surface for construction and industrial purposes. Similarly, it is not advisable and risky to use the restored earth's surface for agricultural and forestry purposes after filling the cavities with waste rocks, since minerals are usually mined in heavily polluted industrial regions, such as, for example, the Kryvyi Rih Iron-ore Basin [4]. It remains strategically feasible to use the restored land areas for construction and industrial purposes, which will make it possible to cost-effectively develop various infrastructure projects in industrial regions, but it requires a geomechanically stable earth's surface level. Therefore, it is necessary to change the approach to performing mining-technical reclamation.

A perspective and highly promising direction for restoring the earth's surface could be the development of technologies for backfilling surface technogenic cavities and further creating a geo-

mechanically stable earth's surface level, which has not been sufficiently studied to date [5]. It is necessary to revise the concept of the mining-technical stage of reclamation in the direction of transformation from a bulky mass into a monolithic backfill mass. On the one hand, this approach increases costs, but, on the other hand, it is strategically important for improving the environmental situation and the development of infrastructure projects, as well as for the regional economy in the future. The mining industry invests heavily in the construction of new dumps and tailing dams rather than in the development of backfill technologies.

It is advisable to implement the backfill technologies in the immediate presence of technogenic cavities and sufficient reserves of backfill material nearby. Thus, a new concept of "technogenic cavities - backfill material" arises, which, in fact, is the starting point in the development of technologies for forming backfill mass of surface technogenic cavities. To identify promising "technogenic cavities - backfill material" systems, it is necessary to study the spatial location of active and closed quarries, formed failure zones and potential accumulations of industrial wastes as backfill materials on the territory of Ukraine.

For the successful implementation of the "technogenic cavities - backfill material" systems, there are a number of important conditions that play a key role in the successful and sustainable implementation of the earth's surface restoration technology, based on the formation of a stable backfill mass:

- the presence in the subsoil of formed technogenic cavities (quarries, failure zones);
- availability of a sufficient mineral and raw material base of backfill materials;
- technical and economic feasibility;
- environmental safety;
- social approval;
- compliance with legislation and adopted regulations.

Ensuring these conditions is important for the sustainable and successful implementation of the "technogenic cavities - backfill material" system in order to restore land resources and ensure sustainable development of the regions.

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GEODETIC MONITORING OF DEGRADED LANDS DUE TO COAL MINING

Modern industrial activities, including coal mining, play a vital role in the global economy. However, they also have significant adverse impacts on the natural environment. Land degradation resulting from mining operations is a critical concern, as it can lead to long-lasting ecological problems. This scientific work explores the topical subject of geodetic monitoring of degraded lands in the context of coal mining and its role in promoting rational nature management.

Geodetic monitoring provides a means to timely detect and monitor changes on mining-affected lands. This technology facilitates more efficient and sustainable natural resource management, leading to the preservation of the environment.

There are the key geodetic methods used for this purpose [1-5]:

- Global Positioning System (GPS) operates by triangulating signals from a network of satellites to determine precise coordinates on the Earth's surface. To monitor land subsidence and mass deformation, GPS receivers are strategically placed on stable reference points and periodically measure their positions over time. Changes in the receiver positions can then be used to calculate ground movements accurately.

- Precise Leveling. Precise leveling surveys are conducted by precisely measuring height changes using leveling instruments, such as digital levels or laser instruments. This method is especially valuable for monitoring gradual, long-term subsidence.

- Interferometric Synthetic Aperture Radar (InSAR). InSAR is a remote sensing technique that utilizes radar satellite data to detect ground movements. It works by comparing radar images of the same area acquired at different times.

- Ground-Based LiDAR (Light Detection and Ranging). LiDAR is a surveying method that uses laser light to measure distances with high precision. Ground-based LiDAR systems are employed to create detailed 3D models of the Earth's surface. By comparing successive LiDAR scans, it is possible to detect changes in terrain elevation with exceptional accuracy.

- Total Station Surveying. Total stations are optical and electronic instruments used for precise angle and distance measurements. When employed for geodetic monitoring, total stations can measure changes in elevation and horizontal displacement accurately. Total station surveys are particularly valuable for monitoring localized subsidence around mining operations.

Each of these geodetic methods has its advantages and limitations, making them suitable for different monitoring scenarios. These methods play a pivotal role in assessing the impact of mining

activities on the landscape and are essential tools for informed decision-making in rational nature management and environmental conservation.

This work aims to establish the relationship between lowering the earth's surface and bearing pressure above the advancing longwall face of Western Donbas mines. The paper presents a solution to the problem. It is based on the analysis of geodetic instrumental observations of the earth's surface lowering and rock mass deformation above the advancing longwall face. Length and propagation in the roof and floor of the extracted seam are the main geometrical parameters of the zone of high rock pressure. Currently, the quantitative parameters of this zone are not considered. And its length under the conditions of Western Donbas is determined with an accuracy of 50%.

The experimental basis for the research includes the results of observations performed at two vertical borehole extensometers and the results of data processing obtained at more than 30 observation stations on the Earth's surface (fig.1).

Fig. 1. The result of the impact of compression of the earth's surface on the concrete road pavement

By now, the instrumental observations of the rock mass deformation have been performed in conditions of the Western Donbas mines. The rocks are soft thin-laminated clayey siltstones and mudstones with UCS 15-30 MPa, and the depth of mining is from 100 to 550 m. The observations involve using the following methods:

- mine surveying observations at observation stations consisting of lines of benchmarks placed in underworked roadways (2 case studies);

- mine surveying observations of the displacement of anchors of borehole extensometers (2 borehole extensometers, 10 anchors in each borehole);

- a geophysical survey in vertical boreholes drilled from the Earth’s surface (1 observation station, 2 boreholes);

- mine surveying observations of the support deformation of the underworked roadways.

The first two methods are of practical interest, in terms of the quantitative assessment of the values of the rock mass displacement and deformation.

To identify the patterns of the rock mass deformation during the longwall face advances at the Stepna mine in Western Donbas, extensometer anchors were set up in boreholes №35 and №2.

Mine surveying observations were conducted simultaneously at the borehole extensometers №35 & №2 and on-surface observation stations №13 & №12 respectively. The depth of mining was 100-110 m. In borehole extensometer №35, anchors were installed at a depth of 56-82 m with an interval of 5-6 m. In borehole extensometer №2, anchors were set up at a depth of 57-77. The time interval between observations was 1-7 days. A total of 96 observation series were performed.

Thus, the research specified the geometrical parameters of the zone of high rock pressure and the nature of the vertical stress distribution within this zone. The paper introduces a method to determine a coefficient of stress increase above the advancing longwall face of Western Donbas mines. We also established the empirical coefficients of the vertical stress distribution function within the abutment pressure zone. There is a relationship between the lowering of the earth's surface and the values of the stress increase in the borehole edge part. The reliability of the obtained results is confirmed by geophysical studies in Western Donbas, as well as by the results of field observations.

Conclusion

The interplay between land subsidence and mass deformation due to coal mining underscores the importance of responsible mining practices and environmental stewardship. Geodetic monitoring plays a pivotal role in quantifying and understanding these phenomena. As the demand for coal persists, it is imperative to strike a balance between energy production and environmental sustainability through rigorous monitoring, establishing the parameters of the zone of influence of mining operations and mitigation strategies.

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DISPOSAL OF PLASTIC WASTE IN THE LEGAL ASPECT

Every year, approximately 400 million tons of plastic are produced in the world, but not even 10% is recycled. Most of them end up in landfills or incinerators. The reasons for this state of affairs include legal inconsistencies, high costs, and there is also the problem of solutions on a global scale.

Due to the increasing production of various types of waste, the processing of which is problematic, the legislative system has introduced the concept of EPR (Extended Producer Responsibility). The European Commission defines it as the full or partial responsibility of the manufacturer for the product, extended to the life cycle of the product in its post-use state. This is to encourage manufacturers to analyze the life cycle of their product already at the design stage.

The principle of Extended Producer Responsibility (EPR or ROP) was included in Resolution No. 96 of the Council of Ministers of June 12, 2023 on the National Waste Management Plan 2028 (M.P. 2023, item 702) [1]. So far, the packaging waste management system was based on the responsibility of entrepreneurs who placed packaged products on the market. They had to achieve the required levels of recycling and, from 2022, also recovery. The second component of the waste management system were municipalities, and more specifically, the obligation imposed on them to selectively collect waste for recovery and recycling. It will be changed as a result of EU directives and the resulting changes in Polish law. This will happen primarily due to the Act of April 14, 2023 amending the Act on the obligations of entrepreneurs regarding the management of certain waste and on the product fee and certain other acts (Journal of Laws of 2023, item 877) [2], commonly known as the "ROP Act", while the previously mentioned directive is called the "Plastics Directive" or "SUP" from the phrase "single use plastic". Current problems with plastics mainly concern single-use plastic packaging, because they are the most produced and therefore require legal changes, incentives for their processing and restrictions on their production. ROP obliges producers to ecodesign, which means using such design solutions or processes in production to facilitate the reuse and processing of waste generated from products, as well as to finance and organize waste collection and processing systems for their proper management.

Obligations related to the SUP Directive entered into force in Poland on May 24, 2023, although some of them are to enter into force at a later date, for example due to the "Draft regulation of the Minister of Climate and Environment on fee rates for single-use products" currently under review. plastics being packaging" and "Draft regulation of the Minister of Climate and Environment on fee rates to cover the costs of waste management from single-use plastic products and the creation and maintenance of public collection systems for this waste", which are to enter into force on January 1, 2024 r. Such rapid implementation of changes is related to the introduction by the European Union of a fee of EUR 0.80 for each kilogram of non-recycled plastic waste, however, member states with a GDP lower than the EU average, including Poland, have negotiated a reduction in payments. Our country will only pay the surplus compared to the amount of EUR 117 million per year. This amount is to be paid to the EU budget by the Ministry of Finance; this amount may be paid from the funds of a given Member State or collected as tax. In Poland, it was decided to use the second method, in the form of a packaging fee unrelated to the product fee, which currently

amounts to PLN 2,70 per 1 kilogram of packaging material placed on the market, but this amount can be reduced by signing an agreement with a recovery organization. The planned packaging fee is PLN 0,20 per 1 kilogram of food containers, packages and wrappers made of flexible materials containing food intended for direct consumption from the package or wrapper without further processing, beverage containers with a capacity of up to three liters, beverage cups, including their lids and lids, lightweight plastic shopping bags and PLN 0,01 per unit of tobacco products with filters containing plastics and filters containing them sold for use with tobacco products, pre-moistened personal hygiene wipes and pre-moistened wipes for home use, balloons, except balloons for industrial or other professional uses which are not distributed to consumers. These fees are intended to limit the use of plastics, because currently, due to their low price and excellent parameters, they are used too wastefully, which causes problems with their management when they become waste.

Due to the excessive use of plastics, from July 3, 2021, it is prohibited in Poland to place single-use plastic products on the market, such as cotton buds, plates, straws, cutlery, including spoons, forks, knives, chopsticks and drink stirrers, as well as balloon sticks with their attachments, as well as food containers and cups made of Styrofoam. Exactly three years later, on July 3, 2024, the obligation to use disposable packaging with permanently attached caps or lids will come into force, because currently there was a problem that caps in sorting plants often ended up in the undersieve fraction and were therefore not subjected to recycled and went straight to thermal disposal.

The environmental strategy of the European Union is also related to increasing the use of recycled plastics in the production of packaging, therefore the KPGO 2028 forecasts include a provision that from 2025, the production of PET bottles will be obliged to have a minimum 25% share of recycled plastics, while five years later it should be at least 30%. To achieve this goal, it is necessary to improve selective waste collection, therefore by 2025, 77% of bottles introduced to the market are to be collected separately, and in 2029 this share is to increase to 90%. Talks are still ongoing about introducing a deposit system for plastic bottles, including the introduction of PET bottles with thicker walls, which can be used similarly to glass bottles collected on deposit. A similar system already operates in Germany - the walls of such bottles are so thick that crushing them with bare hands is almost impossible, which translates into their longer life. The problem is that in May 2023, only one company in Poland distributed bottle dispensers, and the introduction of the deposit system will result in a huge demand for them. The planned deposit system would cover PET bottles with a capacity of up to 3 liters, reusable glass bottles with a capacity of up to 1,5 liters, as well as aluminum cans with a capacity of up to 1 liter, while retail units with a sales area exceeding 200 m^2 would be obliged to collect them. The introduction of the deposit system is planned for January 1, 2025.

The Act "Amending the Act on Packaging and Packaging Waste Management and Certain Other Acts" of July 13, 2023 (Journal of Laws of 2023, item 1852) [3, 4] imposes on those who place packaging covered by the deposit system on the market obligation to label them.

On the Internet, you can also come across the planned introduction of a legal obligation to label packaging, which would indicate how to selectively collect it. It would be in such a form that blind and visually impaired people could use it, but for now there is no information about this issue being clarified. All we know is that it would fall under Extended Producer Responsibility.

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RESOURCE-SAVING TECHNOLOGIES OF MAIZE GRAIN PRODUCTION ON IRRIGATED LANDS

In connection with the global warming of the climate, the need for water for irrigation of crops is increasing. In recent years, the cultivation of corn on irrigated lands has significantly expanded on a global scale, due to its high potential productivity, fodder, food, and technical qualities, the possibility of improving the technologies of its cultivation, and other factors.

The creation and introduction into the production of high-performance hybrids in combination with intensification factors ensured a significant increase in the yield of corn grain and brought it closer to the level of potential productivity. For example, in the state of Michigan (USA) they received a record yield of corn grain - 22,1 t/ha, and in other states of this country at the level of 16,0 t/ha. Currently, the world corn grain market is controlled by four main producing countries: the USA, China, Brazil, and the European Union, so these countries account for about 75 % of the total world grain harvest of this crop.

Corn belongs to highly energy-intensive crops, therefore the issue of optimization of energy consumption under various technological schemes of crop cultivation is particularly relevant now. The increase in the yield of corn occurs mainly due to additional investments in anthropogenic energy, which materializes in the form of new varieties and hybrids, irrigation, fertilizers, means of plant protection disease control, etc.

Analyzing the calculations of the structure of production costs, it was established that when growing different hybrids of corn on irrigated lands in Ukraine, the maximum costs required for mineral fertilizers and fuel and lubricants (26,2-27,6 %, respectively) of the total direct production costs. A large share (about 19 %) is occupied by amelioration costs, which is connected with the need to carry out vegetation irrigation and the high costs of funds for the organization of the irrigation method itself directly in the field. Other components of the structure of production costs in the production of corn grain are less important: labor costs - 9,0 %, maintenance of fixed assets - 6,7 %, seeds - 3,5 %, plant protection products - 4,8 %, and transport costs expenses - 2,1 %.

This structure of production costs confirms the need to develop resource-saving cultivation technologies and reduce energy costs per unit of production. One of the ways to increase the efficiency of energy use in the production of plant products is to optimize technological techniques and increase the yield of products per unit area. Energy analysis, which is a concentrated expression of the law of energy conservation and transformation, allows you to compare energy consumption and energy content in the obtained crop.

The calculation of energy costs for all components of the technological cycle of growing corn hybrids showed that the most energy-intensive are energy costs for vegetation irrigation, soil cultivation, mineral fertilizers, fuel and lubricant costs, and the load on the machine-tractor fleet.

To reduce energy costs and save energy resources in the production of corn grain on irrigated lands due to the introduction of a new direction of chemicalization of global crop production - chemigation, which combines methods of applying herbicides, mineral fertilizers, insecticides, fungicides, trace elements, growth regulators, meliorants, etc. with water. As soon as such a fruitful concept appeared, it immediately gained numerous supporters in many countries of the world, including Ukraine.

The introduction of chemical agents with irrigation water allows for more uniform distribution of them over the area, more accurate dosing, timely feeding and measures to combat weeds, diseases, and pests of crops, prevent soil salinization and environmental pollution, expand the technological and technical capabilities of irrigation systems due to multi-purpose use of irrigation equipment.

The effectiveness of fertilizing irrigation in Ukraine began to be studied in the 30s of the last century. The data of studies on the use of mineral fertilizers together with irrigation water in the USA aroused interest. However, large-scale chemigation became possible only in the 1980s thanks to scientific and technical progress in the development and improvement of irrigation systems and sprinkler technology, the creation of new equipment designs for the introduction of chemicals into irrigation water, the further development of the theory of mineral nutrition of plants and the creation of new types of fertilizers.

Chemical treatment primarily involves the application of mineral and organic fertilizers, microelements, chemical meliorants, soil structure improvers, and systemic pesticides, as well as the application of various preparations of contact action. Implementation of these options can be carried out according to various technological schemes. Agrochemicals in the solid, liquid, and gaseous state can be used for chemigation , but for solid components, mother solutions are pre-prepared before dosing into the flow of irrigation water (Kiver and Onopriienko, 2016).

The application of fertilizers with irrigation water (fertigation) fundamentally solves the problem of uniform distribution of nutrients in the active soil layer to the level of uniform distribution of irrigation water. An important advantage of this method is also the possibility of supplying dissolved fertilizers in small doses during the growing season without damaging the plants both mechanically and through chemical burns (Kiver and Onopriienko, 2019).

This method allows you to combine such energy-intensive operations as the introduction of fertilizers, herbicides, microelements, vegetation watering, operations with fewer passes on the field of powerful tractors with trailers, fertilizer spreaders, sprayers, and other means of mechanization that deform the soil.

Experiments conducted at the Institute of Grain Crops of the National Academy of Sciences of Ukraine showed that after fertigation, the yield of corn increases by 5-10 %. The scheme of applying nitrogen fertilizers showed itself better, according to which the full rate of nitrogen was applied with irrigation water in small, equal doses after sowing, in the phase of 10-12 leaves, throwing out panicles, and the beginning of milky grain maturity. This scheme ensured an increase in grain yield by 11,2-12,3 %. However, the individual elements of this measure in the system of programming the harvest of crops (terms, doses, methods of fertigation, environmental factors) have not yet been sufficiently studied (Kiver and Onopriienko, 2016).

Long-term research conducted by us at the Dnipro State Agrarian and Economic University on ordinary medium-loamy chernozems established the optimal norms, methods, and timings of applying mineral fertilizers with intensive corn cultivation technology. The technology of growing the Pioneer 3978 corn hybrid was generally accepted for this crop in the Northern Steppe zone of Ukraine. Irrigation was carried out with a sprinkler unit DDA-100MA with a specially equipped hydraulic booster. The irrigation regime provided maintenance humidity soil in the active layer is not lower than 70-80 % from the lowest moisture content of the soil.

As a result of the conducted research, it was established that cultivation of corn by intensive technology on irrigated lands in the Northern Steppe of Ukraine nitrogen fertilizers expedient to make retail with irrigation water in the following proportions: 40 % of the whole doses in the period of 10-12 leaves, 40 % - in the ejection phase panicles and 20 % in the milk phase grain maturity. For such an application nitrogen fertilizers on average yield of corn grain increased by 2,72-4,36

t/ha than without fertilizer application. The application of high rates of mineral fertilizers and application of nitrogen fertilizers with irrigation water did not affect the content of nitrates in grain which, in turn, did not worsen him quality indicators.

The research results testify that a combination watered from the introduction of mineral fertilizers (fertigation) is an effective way of saving energy and material resources, increasing the yield and quality of corn grain harvest, and protecting soil from degradation.

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CURRENT ISSUES OF WATER SUPPLY OPTIMIZATION IN UKRAINE AT THE ACCOUNT OF GROUNDWATER

Water resources are vital for the existence and exploration of mankind, their lack or low quality can be a threat. The distribution of water resources in the world, including on the territory of Ukraine, is extremely uneven.

The problem of providing the population with high-quality drinking water has always been relevant. It is known that surface water as a source of drinking water supply is extremely vulnerable in modern conditions. The qualitative state of surface waters under man-made load conditions does not contribute to their safe use for drinking water supply.

Water supply in cities and industrial-urban agglomerations is also characterized by significant risks to public health, as water for drinking water supply is used repeatedly after purification, disinfection and other procedures. The choice of a water supply source largely determines the nature of the system itself, the presence of certain facilities in it, and thus the cost.

Reliability of water supply and public access to quality drinking water are increasingly dependent on the use of groundwater. It is advisable to consider groundwater as a source of drinking water in order to increase the potential sources of water supply, given their inherent advantages, including protection from pollution and wide distribution.

Groundwater protection from pollution is understood as a complex barrier function of the upper part of the geological environment, which is determined by the degree of development of shielding

(layers with low permeability), capacitive, physical (sediments or rock fractions with high porosity, dispersion) and geochemical (sorption) barriers. The protective role of the geological environment is assessed by the protective properties of the transit or cover rock layer from the ground surface to the assessed horizon, where contaminated surface water infiltrates (*Shestopalov et al., 2007*). If we also take into account the protective properties of the water-bearing rocks of the assessed horizon, we can talk about even greater protection of groundwater.

The concept of "groundwater protection" implies the presence of various "obstacles" in natural conditions on the path of pollutant migration that are impermeable or impede the penetration of pollutants into the aquifer both from the ground surface and from the recharge areas.

Among the natural factors that serve as natural mechanical or physicochemical barriers, the following are usually distinguished (*Rogovska*, *1998*).

- aeration zone (capacity of the aeration zone, lithological composition of rocks, water-physical, sorption and other properties of rocks)

- regional aquifer, which lies first from the surface, where groundwater is formed (nature of its distribution, thickness, lithological composition of rocks);

- hydrodynamic isolation of the main aquifer (conditions of feeding, drainage of groundwater and pressure water);

- vegetation cover;

- chemical composition of groundwater in this horizon;

- water-physical (filtration) properties of rocks of adjacent aquifers;

- local conditions of intensive filtration (physical and geological processes: karst, fractured rocks, etc.

In order to determine the degree of protection (vulnerability) of groundwater from pollution in different parts of the studied territories, it is necessary to assess the impact of various hydrogeological, physical and chemical conditions and factors that affect their protection (vulnerability). The result of this assessment is the division (zoning) of the study area into areas or zones with different degrees of protection (vulnerability), characterized by greater or lesser relative protection (vulnerability) of groundwater.

These areas should roughly correspond to areas or zones of relative homogeneity of hydrogeological conditions, filtration and migration parameters of the geological environment, which are the most significant factors of groundwater protection (vulnerability): filtration conditions, permeability and capacity characteristics of the aeration zone, saturated aquifer rocks, etc. In addition, the status of the existing issue of accounting and utilization of operational groundwater resources should be taken into account (*Koshliakov et al.*, *2014*).

Over the past decades, Ukraine has seen significant changes in regional water use. Previously, the assessment of projected groundwater resources was mainly focused on large water consumers (regional and district centers, large industrial enterprises). The problems of establishing the prospects for the needs of small water consumers were not taken into account at all. Therefore, the total groundwater withdrawal by small geographically sparse water consumers is largely unknown, and this value is quite significant for the territory of Ukraine. In addition, the groundwater withdrawal patterns that were used as a basis for the forecasts have changed considerably. An example is the change in water withdrawal from the "big wells" of Kyiv (*Koshliakov et al*., *2012*). Such changes have led to a significant transformation of the filtration field, changes in groundwater levels and flow direction. Incomplete accounting of groundwater infiltration recharge, on the one hand, reduces the reliability of forecasts, and on the other hand, does not sufficiently take into account the processes of pollutant transfer due to infiltration flow (*Koshliakova et al., 2021*, (*Koshliakov et al., 2022*).

Unfortunately, very often, when justifying water withdrawal, the possible negative impact on the environment is not taken into account.

The business environment in Ukraine has changed significantly. Some territories are actually beyond the areas of possible assessment. The forced exploitation of groundwater as a result of emergencies is not taken into account, as well as the issue of protection of groundwater resources. Significant anthropogenic load on the underground hydrosphere contributes to the formation of regional and local depression funnels. Increased pollution of soils, surface waters, agricultural landscapes, industrial and urban agglomerations, and war zones will inevitably lead to changes in groundwater quality. We should not forget about the change in the interaction between surface and groundwater and the accelerated migration of pollutants into groundwater aquifers and the increased vulnerability of aquifers in the active water exchange zone.

Along with groundwater exploitation in areas with reasonable reserves, unauthorized drilling (often with violations of drilling technology) of deep aquifers often occurs, thus increasing the intensity of man-made pollution of drinking aquifers.

Reasonable expansion of the use of drinking groundwater will help improve the quality of municipal drinking water supply to cities and individual water consumers.

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PROSPECTS FOR RECYCLING TRIPLEX IN A VIBRATORY JAW CRUSHER WITH AN INCLINED WORKING CHAMBER

Triplex is a composite material that includes sheet glass firmly bonded with polyvinyl butyral film. Due to its safety in case of destruction, it is widely used in the glazing of cars, railway rolling stock, aircraft, ships, houses, shop windows, the manufacture of suspended ceilings, interior partitions and many other structures. Currently, the amount of triplex produced is millions of tons and is constantly increasing. At the same time, the volume of glass that has become unusable and requires disposal increases, gradually creating a serious environmental problem. The accumulation of triplex waste is associated with the complexity of its processing and the lack of effective technologies and equipment. Analysis of literature sources allows us to determine the basic design diagrams used for the development of crushing and grinding equipment.

In the mechanical processing of triplex glass, a multi-stage technology of interaction of triplex with rotating rollers having a lining surface of various shapes is widely used [1].

One of the directions for creating equipment may be technology based on the use of the electro-hydraulic effect [2].

At the Slovak University of Technology in Bratislava, experimental studies were carried out on the separation of glass from the interlayer film using high-frequency impact [3]. The studies were carried out on a vertical impact tester and a model simulating a vibratory jaw crusher with a vertical crushing chamber and translational movement of the jaw. One type of lining plate with a wavy shape of the working surface was used. Despite the fact that the equipment used is limited by ad-

justable technological and design parameters, the results obtained showed the ability of vibration impact to effectively remove the glass component of triplex.

Work on vibration-impact destruction of materials and the creation of crushing and grinding equipment is carried out at Dnipro University of Technology [4].

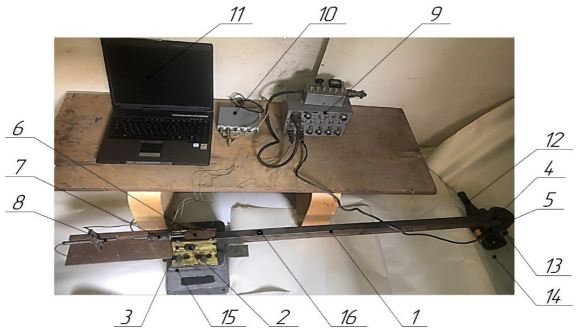

Fig. 1. Horizontal pendulum impact tester: *1*- pendulum; *2* - suspension axis; *3* - housing; *4* - replaceable load; *5* - impactor; *6* - curvilinear bar; *7* - following mechanism; *8* - displacement sensor; *9* - vibration measuring equipment; *10* - USB oscilloscope; *11* - laptop screen; *12* - material under study; *13* - acceleration sensor;*14* - base; *15* - gaskets; *16* - level

An analysis of the results obtained for processing triplex showed the feasibility of conducting research with simultaneous exposure to shock and shear loads on the material.

The initial stage of work was carried out on a horizontal pendulum impact tester (Fig. 1), the design and principle of operation of which are described in [5].

Fig. 2,3 show fragments of destruction of the glass component of a triplex on pendulum impact tester in one blow.

The angle of inclination of the destruction chamber is 30°, the working surface is prismatic spikes.

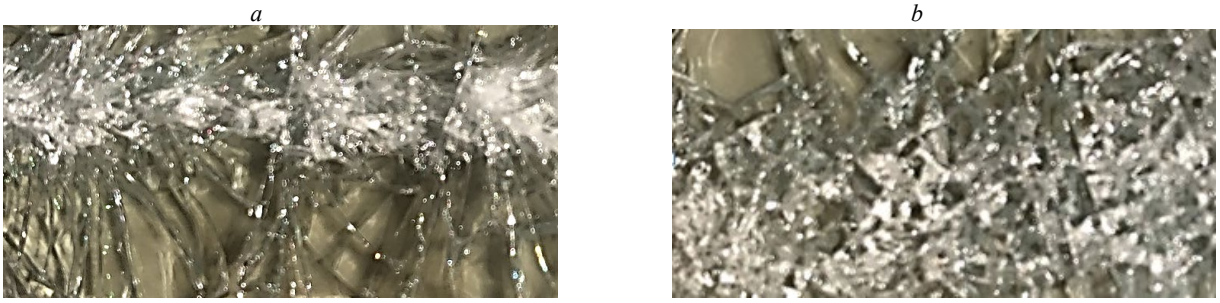

Fig. 2. Fragments of destruction of the glass component of the triplex upon contact with the impactor:
a - shock loads on the material; *b* - shock and shear loads on the material

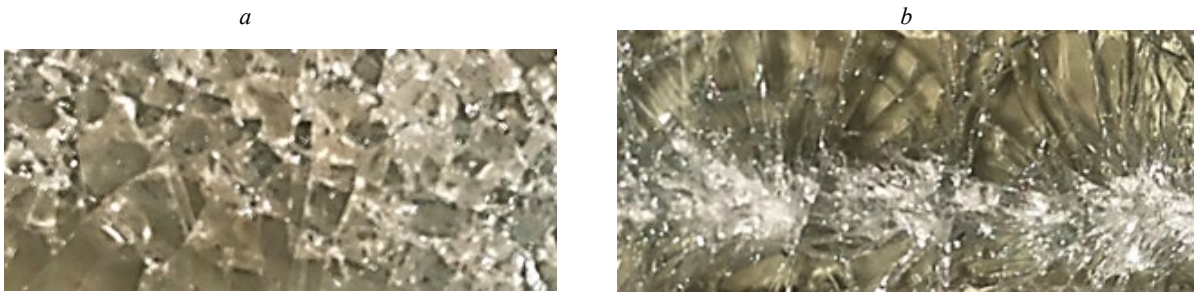

Fig. 3. Fragments of destruction of the glass component of the triplex upon contact with the base:
a - shock loads on the material; *b* - shock and shear loads on the material

The presented results showed the effectiveness of using shear under shock loading. The removal of broken glass per blow increased by 15%. The conducted research served as the basis for the design of a vibrating jaw crusher with an inclined crushing chamber, providing shear load at the moment of impact.

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IMPACT OF TECHNOLOGICAL CHANGE ON THE ECONOMY AND RESOURCE MANAGEMENT IN LEAST DEVELOPED COUNTRIES (LDCS), POSSIBLE SOLUTIONS: THE EXPERIENCES OF THE CIRA-UGANC-BOCEJ PROJECT – REPUBLIC OF GUINEA

Abstract

The technological evolution of recent years has led to a change in professions around the world; This has a serious impact on the economy and resource management of the Least Developed Countries (LDCs) and slows down Africa's growth, which remains weak. However, Africa could make better use of its natural resources in times of high demand linked to the energy transition, but one in five companies cannot find the skills they are looking for.

The project "CIRA – UGANC BoCEJ" is a sub-project of the BoCEJ and aims, among other things, to improve the economic efficiency of enterprises by adapting university training programmes to the needs of the market and to provide new professional opportunities through training.

This article presents CIRA-UGANC-BoCEJ through the approach used, the results obtained, the handicaps/difficulties encountered, the proposed solutions as well as the lessons learned.

Keywords: CIRA-UGANC-BoCEJ – Industrial Control and Automatic Regulation sub-project, Gamal Abdel Nasser University of Conakry, Project BoCEJ (Boosting Skills for Youth Employability), World Bank funding.

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IMPROVEMENT OF THE DESIGN OF THE HYDRO-PUMPING UNIT OF THE POLDER DRAINAGE SYSTEM IN ACCORDANCE WITH CURRENT CHANGING CONDITIONS AND REQUIREMENT

During the many centuries of living in the zones of possible flooding, mankind has developed and applied in practice one of the most effective measures against this phenomenon - it is protection against flooding by earth dams with mechanical drainage, i.e. polder drainage systems. Currently, all countries, including Ukraine, on whose territory there are periodically flooded river, coastal, and lakeside lands, are implementing projects to protect lands from flooding in order to increase the efficiency of agricultural production, as well as protect settlements from flooding.

Modern problems related to the energy, water, and food crises, which are intensifying under conditions of climate change, threaten the economic and social development of the global population. The growing demand for food products, water and electricity is already leading to their shortage. The aggravation of these modern problems under the influence of changes in climatic and anthropogenic factors determines the necessary development and implementation of appropriate adaptive measures in the area of drainage reclamation.

These measures are necessary to improve the efficiency of agricultural production on drained lands by improving water regulation technologies, the type, design and parameters of drainage systems. They are necessary to increase, first of all, the energy and general efficiency of polder drainage systems as the most high-tech water regulation facilities in the Western Polissia of Ukraine.

On the territory of the Western Polissia of Ukraine, the area of drained land is 1232,4 thousand ha. At the same time, the area covered by polder drainage systems with guaranteed mechanical drainage is 96,7 thousand hectares.

Currently, the existing polder systems are characterized by the following changes in the conditions of their operation: a significant increase in the cost of energy resources; wear and tear of pumping and power equipment and other technical elements of the system (silting of reclamation channels, collector and drainage network, unsatisfactory technical condition of hydrotechnical structures on the system, etc.); violation of design parameters and a decrease in both the technological (reclamation) and agricultural efficiency of reclaimed lands (a decrease in their productivity by 25-50% against the design); emergence of environmental problems (flooding of agricultural lands, strengthening washing regime of drained soils); low level agricultural production and use of drained lands polders, their unsatisfactory ecological and remedial state, etc.

Based on the generalization of long-term data observations of the efficiency of the drainage polder system "Birka" with an area of 544,9 hectares, which is located on the floodplain of the Styr River in the Rivne region, in changing conditions we improved the design of the pumping unit of the drainage polder system due to the arrangement of additional gravity elements in the form of a siphon outlet and a puncture in the body of the protective dam.

The design of the pump-out hydraulic unit was improved, which included: a protective dam, subducts (main channel), an outlet for gravity drainage, an advance chamber and a pumping station. In the hydraulic unit of the polder drainage system, a pumping unit consisting of a pumping station and an advance chamber was allocated, which was it is proposed to equip with two gravity elements - a siphon-type water outlet and a puncture in the body of the protective dam, which is equipped with a through pipe with a damper at the entrance and a non-return valve at the exit for unloading it work.

Siphon outlet, as one of the additional gravity elements, it can work both in critical periods of the year and in periods of insignificant load, but only in a certain range of water level differences and as the pumping costs are triggered and the pressure decreases, they are automatically turned off, and the drainage is subsequently carried out by a pumping station and a gravity water outlet. Disadvantages of the design are the limited possibility of water removal with a siphon outlet when the water levels in the advance chamber decrease.

Since the siphon-type water outlet has a limited capacity, due to the reduction of water levels in the advance chamber, a puncture in the body of the protective dam complements its operation and can work both together with the pumping station and with the siphon-type water outlet, and separately with each of them (as an auxiliary element).

And in conditions of insignificant load, as the main element for the removal of excess wastewater together with water release gravity drainage. A puncture in the body of a protective dam is a basic element that is involved in the operation of the pumping unit of the drainage polder system both in the critical period of passing surface runoff and in the period of overflow.

The hydro node of the polder drainage system works as follows. Water from the drained lands enters the main channel, is diverted to the advance chamber, and from there is pumped to the water receiver by the pumping station through the pressure pipeline.

Also, the design can provide for additional gravity removal of water from the territory of the polder drainage system at appropriate water levels in the water intake. The disadvantage of such a design of a hydraulic unit is the significant consumption of electricity, the impossibility of operational management of costs, since the range of regulation expenses is limited by the performance of the pumping station or separate pump.

During the period of maximum load of the hydraulic unit pumping out the polder drainage system during the passage of a flood or flood, all its components are included in the operation: water outlet for gravity drainage, pumping equipment, siphon-type water outlet, puncture in body of the protective dam.

Water from the drained lands is diverted to the advance chamber through subducts (main channel). At three elements of the node work at full load pump outs: pumping equipment, siphon-type water outlet, puncture in the body of the protective dam.

When the siphon-type water outlet and the pumps that were involved in the work in a more critical period of time are turned off, as a result of the decrease in the water level in the advance chamber, the water continues to drain by gravity through the puncture in the body of the protective dam, moving through the open valve at the entrance of the passage pipe and is discharged through the non-return valve at its exit to the water receiver, which ensures further water drainage and lowering load on the operation of pumping equipment.

Compared to the existing hydraulic pumping units, the proposed design of the pumping unit with a siphon water outlet and a puncture in the body of the protective dam, depending on the water level of the year, makes it possible to increase the efficiency of the polder drainage systems by 20-40% for due to the reduction of the load on the pumping equipment by redistributing the pumping flow to the corresponding component gravity elements of the pumping unit.

Thus, the improved design of the pumping unit of the drainage polder system with additional gravity elements during their joint operation will reduce the load on the pumping equipment, the duration of its operation and, accordingly, the cost of electricity due to the removal of the corresponding parts of the surface runoff will accelerate drainage from the polder drainage system in critical periods of their greatest load will ensure the maintenance of the necessary water-air regime of drained soils in different phases of vegetation of cultivated crops.

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FEATURES OF THE USE OF GARBAGE TRUCKS IN THE CONDITIONS OF RURAL AND URBAN VILLAGES COMMUNITIES

In most countries of the world, one of the directions of rational environmental management is the maximum use of solid household waste (MSW) recycling. Today, Ukraine has a much lower percentage of solid waste reuse. Therefore, one of the important tasks of today for the territorial communities of Ukraine is the modernization of the existing solid waste management systems. In most communities, the implementation of technologies for separate collection of solid waste is just beginning. An important and useful aspect in the improvement of waste management systems of various levels is the implementation of advanced European experience, as evidenced by the implementation in Ukraine of a number of programs approved at the state level.

However, it is impossible to simply copy the waste management system of one country in the conditions of another, which has a number of economic, infrastructural and other differences. Therefore, the initial stage of the implementation of the European experience is research and comparison of the conditions of implementation of the relevant programs in Europe and Ukraine.

One of the key technological elements of any waste management system is specialized transport for solid waste collection. Within the framework of this work, we have analyzed a number of research project works on the development of sanitary cleaning schemes of various settlements in Ukraine and the Poltava region in particular, as well as territorial communities of the Poltava region [1-9]. In the course of the study, the peculiarities of the formation and operation of the fleet of garbage trucks in the conditions of settlements with different socio-economic and demographic status were established.

Currently, in Ukraine, garbage trucks are used mainly with side and rear loading, as well as portals for collecting bulky waste. At the same time, in most rural and urban villages communities with a population of the largest settlement of up to 12,000 people, the main type of garbage trucks are side-loading machines. These are mostly outdated models on the chassis of GAZ-3307, GAZ-3309, ZIL-130 cars. As a rule, these cars have a high degree of moral and physical wear and tear. Communities also use rear-loading vehicles. For rural and urban villages communities, the most typical are AT-2121 or VLIV MICRO cars with a body volume of 9 m^3. In communities with a population of the largest settlement of more than 12,000 people, rear-loading cars with a body volume of 12-18 m^3 can be found [1, 2]. Territorial communities of the urban type, which are based on powerful agglomerations [3, 4], mostly have equipment with bunkers of medium and large capacity

(12-33 m^3) in their communal economy. This situation is typical for Ukraine. If we analyze the temporal dynamics of the composition of the garbage truck fleet of objects identical from the point of view of the organization of the waste management system, it is possible to note a rather significant dynamic of renewal and improvement of the fleet of garbage trucks in large urban agglomerations [3, 4] and low rates of renewal in almost all rural and settlement communities.

When using garbage trucks in the conditions of small rural and urban villages communities, a certain dilemma is observed. It consists in the fact that from the point of view of the amount of waste generated per day and taking into account the established normative period of their removal, the most optimal, according to data [2, 5, 6, 7], is the use of garbage trucks with a hopper volume of 8-11 m^3. However, with the widespread implementation of separate collection of solid household waste, the use of such types of garbage trucks is not always optimal from a technological and economic point of view. Considering that the amount of such fractions as paper or glass is insignificant compared to the total volume of waste (respectively 1,3-2% and 7-10%), and a garbage truck with rear loading can load about 150 containers in one working shift, then according to [2, 5, 7], the car will always drive half-empty. In addition, according to [1, 5, 10], the architectural and planning features of settlements with the status of a village or settlement, namely such an indicator as the width of the streets, do not allow the use of large cars. In such cases, it would be advisable to use garbage trucks with a hopper volume of 6 m^3. But small rural and urban villages communities do not have the economic ability to buy garbage trucks for each separate fraction with different volumes of bunkers. Therefore, as a rule, they follow the path of unification of the transport fleet of garbage trucks and purchase cars with a body volume of 9 m^3. Thus, the transport fleet existing in communities is optimal for unitary collection of solid waste and for collection of mixed fractions. However, it is often not optimal for collecting individual fractions of resource-valuable waste.

As part of the analysis of the possibility of optimizing waste management systems in urban and rural territorial communities and bringing their transport and logistics efficiency closer to the European level, it is necessary to note some technological indicators of garbage trucks. An important factor is the average loading time per container. From the preliminary analysis, it can be seen that the side-loading cars available in most townships and villages spend 50-60 seconds per container. In turn, modern modifications of European garbage trucks take about 20 seconds.

Another important factor is the compression ratio. The equipment available in communities with side loading has a typical compression ratio in the region of 1,5-2,5, with a rear - 4-6. In Europe, the compaction ratio of garbage trucks is from four to eight.

Thus, according to the main technological indicators, the majority of specialized garbage collection vehicles available in the territorial communities of the Poltava region need to be updated.

In many European countries, the technical and logistical component of separate waste collection systems is implemented with the help of multi-section garbage trucks.

These are products of world-famous manufacturers such as HIDRO-MAK (ECOTWIN models), NTM (DUO, TRIO and QUATRO models) and other manufacturers.

In Ukraine, the experience of using multi-section garbage trucks is practically absent.

However, in separate project works (for example, "Development of a scheme for sanitary cleaning of 13 settlements of Tereshkiv village council of Poltava district of Poltava region", contract No. 06/01-19 dated 27.08.2019) calculation of the option of using multi-section garbage trucks in schemes for sanitary cleaning of territories was carried out.

These calculations showed greater transport, technological and economic efficiency of using multi-section garbage trucks compared to single-section ones.

Thus, for the territorial communities of Ukraine and the Poltava region in particular, the modernization of transport and logistics support is a necessary and extremely important component of increasing the economic and ecological efficiency of local and regional waste management systems.

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THE INFLUENCE OF COMPLEX BUILDING RENOVATION ON MINIMIZATION OF HEAT LOSSES AND REDUCTION OF GREENHOUSE GAS EMISSIONS

The field of efficient energy use is an integral part of the process of saving energy resources.

The authors of this work propose to consider the following example. The walls of the building are made of brickwork 50 cm thick, where the masonry is two bricks thick. Their area is 102 m^2. The internal temperature of the room is 20 °C. The overlapping area of the floor and roof is 80 m^2. The windows are metal-plastic and meet regulatory requirements. The total area of translucent structures is 6 m^2. The building is located in the city of Zaporizhzhia (II temperature zone).

If the appropriate calculations according to the established methodology are performed [1], it can be clarified that the heat transfer resistances shown do not meet the minimum permissible requirements.

Then, the total heat loss is 25.,7 kW at a temperature of -15 °C, considering that the calculation month is January. Obviously, when the ambient temperature increases, heat loss decreases. But since the external air temperature is an independent parameter, it is possible to influence only the heat transfer resistance of the enclosing structures.

The situation in which the regulatory parameters of the building meet the minimum requirements has been observed [2]. In this case, the total heat loss is 2,5 kW. Therefore, by insulating various enclosing structures and meeting the minimum requirements, it has been established that heat losses can be reduced by approximately 10 times. While there is a financial benefit for ordinary consumers, it is also possible to achieve significant savings in the fuel-and-energy resources.

Moreover, while renovating a building, it is also possible to achieve a reduction in greenhouse gas emissions. There is an appropriate calculation method [3] to determine the effect of the implemented modernization measures.

For the considered building, according to the basic scenario, greenhouse gas emissions amount to 13.28 tons of CO_2, and according to the project presented - 1,44 tons of CO_2. As a result of the energy efficiency improvements of the given building, the possibility of reducing greenhouse gas emissions by 11,8 tons of CO_2 has been calculated.

Therefore, according to the results of the calculations carried out by the authors, it has been found that during the thermal modernization of buildings, it is possible to achieve significant savings in the fuel-and-energy resources due to the reduction of heat losses through the enclosing structures. In addition, there is an opportunity to significantly reduce greenhouse gas emissions.

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DEVELOPMENT OF A CLASSIFICATION SYSTEM FOR COAL MINING WASTE UTILISATION METHODS

The study described in the source [1] considers the proposal to explore the possibilities of increasing the reserves of exhaustible natural resources through the use of coal mining waste. the main idea is to develop cost-effective methods of using coal mining waste as a source of materials with a high content of elements such as aluminium (*al*), gallium (*ga*), germanium (*ge*), bismuth (*bi*), etc., which are of great importance for industry.

In most developed countries, coal-bearing formations are almost entirely used to reclaim mined areas and to produce various building materials such as bricks, pipes, and ceramics. for example, this practice is widespread in Germany, France, Poland and Belgium. the use of pneumatic and hydraulic methods to backfill waste into the already mined space in mining in these countries helps to reduce the amount of waste rock that is removed, prevent surface subsidence, the development of flooding after mining, and limit the construction of cavity walls, which in turn increases the stability of the rock mass [2].

Industrial use of coal mining waste dates back to 1921-1932. The first attempts included the use of burnt coal mining waste with the addition of small amounts of lime and portland cement to produce concrete, which was then used to create wall materials. Later, the crushed burnt rocks were used as fillers in the manufacture of stone and decorative products [3].

The second option involves planting greenery on the surface of the waste heaps, but this approach only helps to limit the size of the sanitary zone near the heaps, but does not solve the main problem.

Finally, the third option is the utilisation of waste heaps, which is considered to be the most promising in solving this problem, the cost of landfill disposal depends on what materials can be extracted during the processing of the dump [4].

One of the most promising uses of coal mining waste is in the construction industry. In addition, coal mining waste contains various chemical elements, such as:

- Germanium, which can be used in the production of plastics, metallurgy, electrical engineering, medicine, optics and solar energy. Germanium can be used in the manufacture of glass and lenses for night vision devices and military guidance systems. The cost of germanium extracted from the dump exceeds $1,000 per kilogram.

- Scandium, which is a soft material and easy to process. It can be used in the aviation and space industries, the automotive industry, and even in the manufacture of dental prostheses. the addition of scandium to iron and steel alloys increases their cost. The cost of scandium ranges from $42,000 to $45,000 per kilogram [5].

- Gallium, a metal used in the production of adhesives and lubricants, as well as in the design of certain types of lasers and thermocouples for solar cells. It is noted that the demand for gallium exceeds its production. The cost of gallium ranges from $1,3 to $1,5 thousand per kilogram.

These methods of solving the problem of using coal mining waste are known and widely used around the world, experts in countries such as:

- Japan, where rare materials are extracted from waste heaps;

- The United States of America, where reclaimed land is used for reforestation;

- Central AND Eastern European countries, where reclaimed land is used for agricultural development;

- The United Kingdom, WHERE reclaimed land is used mainly for recreational purposes, industrial and civil construction, and less often for agriculture [6].

In [7], the author considers the problem of insufficient attention paid by the state to the issue of coal mining waste management. This negligence is manifested in several aspects: first of all, in the presence of enrichment residues on the surface of the dumps, which leads to the need to use land plots suitable for agricultural activities. In addition, production waste interacts with the natural environment, leading to deterioration in air quality and mineral contamination of wastewater. there are also cases of surface deformation, which leads to subsidence of buildings, infrastructure and disruption of aquifers [8].

The most economically feasible way to use coal mining waste is to use it as a source of man-made deposits. According to the data presented in [9], aluminium, germanium, scandium, gallium, yttrium and even zirconium can be extracted from waste heaps, according to these data, coal mining waste rocks contain the following rare elements: germanium - 55 g, scandium - 20 g, gallium - 100 g. the total amount of rare earth elements in the waste heaps is estimated to be in the range of 230 to 260 g/t. table 2 shows the value of the most common rare earth elements contained in coal mining waste, according to the data obtained, the raw materials extracted from one average volume of waste heap are estimated to be worth at least $100 million.

The technology for the extraction of rare earth metals will operate as follows: a special excavator will load the rock onto a belt conveyor, which will deliver it to an industrial building, where it will pass through a crusher and an iron separator (magnetic separation). the process will initially involve the separation of iron and its compounds. later, aluminium and silicon will be fused, followed by the separation of germanium, scandium and other rare metals. the remaining waste (approximately 15-20% of the total volume of rock) can be used for the production of construction materials [10].

Conclusions

The first place in the structure of conclusions is the relevance of timely implementation of highly efficient technologies for the use and processing of coal mining waste at mining enterprises. this will help to prevent pollution of soil, surface and groundwater, and air in the regions where mining waste is located.

The second key aspect is the use of coal mining waste as a source of man-made deposits for the extraction of rare earth elements. this strategy will make it possible to use these elements in industry as a strategic raw material for Ukraine's economic development.

The last but not least conclusion is the possibility of using coal mining waste as an alternative source of geothermal energy. this strategy can significantly reduce the dependence of coal regions on nuclear power and bring significant economic savings to the population living in these regions.

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STUDY OF THE CURRENT HYDRODYNAMIC STATE OF THE TERRITORY OF THE NOVOTROITSK DEPOSIT OF THE VOLNOVASK DISTRICT OF THE DONETSK REGION

The purpose of the study was to analyze the current hydrodynamic state of the territory of the Novotroitsk deposit of the Volnovask district of the Donetsk region and to predict its changes under the influence of backfilling of the flooded space of the Western Dolomite Quarry (WDQ). For the possibility of storing overburden and waste rock and ensuring the removal of additional volumes of water from the WDQ outside the flooded space of the quarry, while minimizing the support of underground waters of the coal horizon within the territory adjacent to the quarry.

Based on the results of the study of geological and hydrogeological conditions, a geofiltration model of the territory of the Novotroitsk deposit was developed, and its verification was carried out based on the results of solving inverse problems and assessing the convergence of actual and calculated data regarding the groundwater level regime and the balance of the combined modeled territories. To assess the impact of backfilling of the flooded production space of the Western Dolomite Quarry on the underground hydrosphere, a numerical geofiltration model was implemented in the Visual MODFLOW software complex, which is a model of the three-dimensional flow of groundwater of constant density in a porous medium. According to the main mode-forming factors, which in natural conditions are infiltration nutrition distributed over the territory and the influence of surface watercourses and reservoirs, the modeled territory is defined in the contours of the main geomorphological elements and the constituent hydrographic network. The man-made elements that improve the natural topography of the studied area include the active Vapnyakivsk quarry, the exhausted Western Dolomite Quarry, and the Olenivsky deposit quarries, as well as overburden dumps.

Taking into account the spatial position of the indicated boundaries, the geofiltration model is defined in rectangular coordinates, respectively, in the latitudinal direction 7386000-7400000 m and the meridional direction 5283000-5292000 m and has a total area of 126,0 km^2 (Fig. 1). The area of the modeled area is discretized by calculation blocks of 100×100 m, which made it possible to display in sufficient detail both the geometry of the modeled objects and the hypsometry of the surfaces of the calculated rock layers, the contours of the internal and external hydrodynamic boundaries and the surface levels of aquifers.

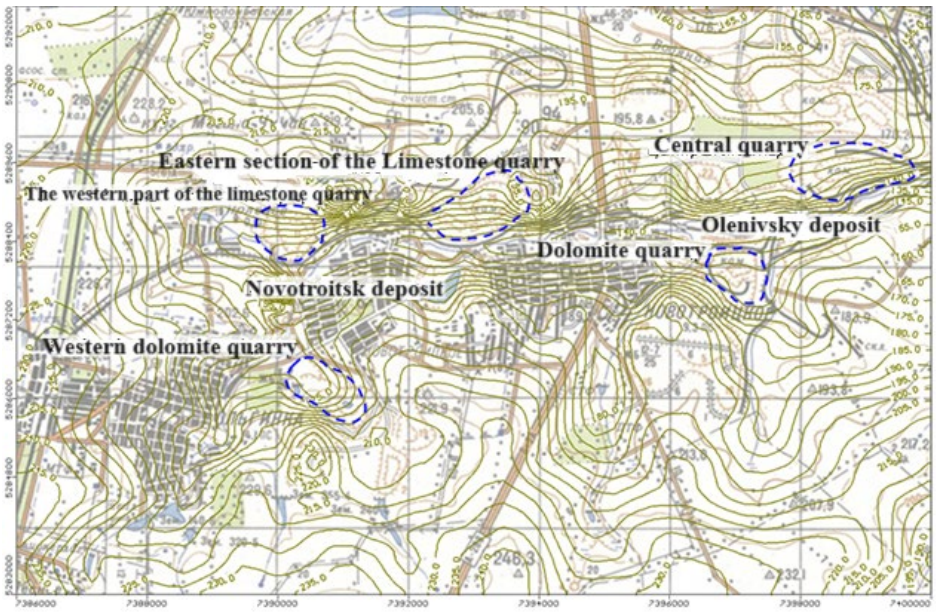

Fig. 1. Geofiltration model of the studied territory, relief of the day surface, m

The hydrodynamic scheme of the modeled area is determined in accordance with the geological structure and hydrogeological conditions of the studied territory, taking into account the external and internal hydrodynamic boundaries, which are the feeding of aquifers on the side contours of the model. The branched river system is represented by the river Sukha Volnovakha and its tributaries, and the draining contours of active quarries of the Novotroitskyi and Olenivskyi deposits.

The hydrodynamic features of the modeled stratum within the specified calculation layers were taken into account by the task of zoning their filtration properties according to the nature of the distribution and occurrence of individual stratigraphic subdivisions.

The criteria for the convergence of the geofiltration model used are the balance components of groundwater - quarry runoff from active quarries located within the studied territory and river runoff flow. And also, the level mode of the water mirror the in the produced space WDQ, established in accordance with the dynamics of its flooding.

According to DBN B.1.1-25-2009 "Engineering protection of territories and structures against flooding and flooding", the maximum depth of groundwater levels for high-rise capital buildings with a soil freezing depth of 0,7 m or more is at least 2,0 m, for low-rise buildings for manor buildings - not less than 1,5 m, for streets, roads, squares, and green spaces - not less than 1,0 m.

The admissible mark of the rise of the water level in the flooded WDQ when the produced space is filled with overburden is determined.

According to forecast calculations as of 2025, the water level will rise from 0,0 to 5,0 m in almost the entire area of the deposit, except for its southern part at the junction with the crystalline massif.

Taking into account the possibility of storing overburden and empty rocks in the spent space of the WDQ quarry. Also, the possibility of exceeding the allowable levels of water in the pit with the

planned volumes of storage as of 2026-2029, it is considered expedient to regulate the volumes of storage for this period, which will ensure compliance with the specified condition regarding the maximum level of water in the pit when it is backfilled.

One of the possible solutions for maintaining the volume of storage of overburden and empty rocks at the planned level without exceeding the maximum permissible rise of the water level in the pit may be the organization of discharging water from the flooded space of the WDQ pit into the river Sukha Volnovakha.

For the period of 2026-2028, the forecast volumes of average daily water consumption (when stored with loam in mind) according to the estimates are 2026-608,22 m^3/day (25,34 m^3/h); 2027-8367,12 m^3/day (348.63 m^3/h); 2028-2502,73 m^3/day (104,28 m^3/h).

A feature of the conducted model calculations is taking into account the moment of change in the storage mode, when the stored rocks occupy the entire produced space and come to the surface of the water, thereby stopping the further pushing out of water by its volume. After the onset of such a period, the actual stage of "dry" storage of rock material in the dump begins.

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JUSTIFICATION OF GLOBAL ENVIRONMENTAL AND ENERGY DECARBONIZATION PROJECTS IN UKRAINE AND ROMANIA

The unique natural complex of components of hydrogen technology in Ukraine and Romania, characterized by the availability of solar and wind energy resources and almost unlimited possibilities of using the main hydrogen component - hydrogen from fresh water that irrevocably flows into the Danube sea area - is considered for implementation (~3000 m^3/sec).

The main parameters that determine the feasibility of a constructive solution to the global energy problem include a wide range of natural factors: geological structure, environmental and climatic characteristics, and one of the most important natural factors of the twenty-first century, as mentioned above, the use of significant amounts of fresh surface water without causing environmental damage.

The research area is located within the Pereddobrudzhynska Depression. It is the southern, deepest part of the East European Precambrian platform in geostructural terms. It is adjacent to the

folded Scythian plate of the Hercynian age, which is the foothills of the Dobrudzha mountain structure. The research area is located in the western wing of the Black Sea artesian basin.

The general meteorological characteristics of the research area. It is also necessary to note such climate forming characteristics as solar radiation, atmospheric circulation and wind regime. The main climate-determining factor depends on amount and duration of Sun radiation that reaches the earth's surface. Amount of solar energy reaching a unit plane at some point of atmosphere upper limit per unit time is called insolation. Amount of total solar radiation during the year for the research territory exceeds 4800 MJ/m^2. Higher values of this characteristic are observed only in certain areas of steppe Crime.

General hydrological characteristics of the research area. The research area territory is confined to floodplain of the Danube River. It is more than 100 km long. Main objects of hydrographic network of the research area are the Danube River and group of Danube lakes.

The Danube lowland has a quite dense network of surface watercourses and reservoirs. Main water bodies in the research area are Danube River and Transdanubian lakes, which form the largest lake region of Ukraine and Romania representing the unique natural complex located in the Danube floodplain. The Danube is the main river of the Black Sea basin. It provides up to 40% of the fresh water inflow to the Black Sea and up to 80% to its northwestern part.

The Danube, whose runoff is formed in a catchment area of almost 817,000 km^2, is characterized by a large variability in absolute values.

Therefore, in the last century average long-term values of the Danube flow were 203 km^3/ year. It value varied from 127 in 1921 to 297 km^3/ year in 1941. In 2001-2010, it varied from 158 in 2003 up to 299 km^3/year in 2010. The flow in 2010 is maximum for more than a hundred years of observations.

Average value of the flow for 2000-2010 is 223 km^3/ year and is almost 10% higher than the average longterm values [Iu. Bogatova].

Table shows that water mineralization in the Danube River does not exceed 470 mg/dm^3 throughout the year and during flood it increase to 370 mg/dm^3.

At the same time, the characteristics are changed slightly along the length of studied section of the river.

Table.

Water salinity (mg/dm^3) in the Danube River

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
	Danube River-Reni											
2011	371	378	392	383	395	404	403	358	369	379	385	421
2012	397	418	412	406	406	390	382	379	381	401	386	383
2013	345	356	370	362	367	417	362	357	333	343	366	363
2014	402	381	369	386	344	325	303	343	329	361	376	355
2015	394	405	441	422	362	338	356	380	363	382	336	368
2016	334	347	352	334	325	330	311	322	322	353	377	365
2017	407	376	308	378	326	350	319	327	289	289	350	347
2018	322	331	355	334	368	324	344	302	308	347	367	377
2019	384	359	358	297	295	276	274	267	324	343	343	363
2020	362	403	327	345	323	346	285	277	277	320	339	353

In recent years, more and more countries have been building floating solar thermal power plants, which do not occupy useful area on water and are effectively cooled. Projects of floating solar power plants were implemented in Switzerland, China, Japan, Great Britain and Australia. In Portugal hybrid power plant was put into operation. It was the plant that combines hydroelectric power plant (HPP) and SPP. Floating solar power plant is a set of solar panels fixed on floating platforms. Floating SESs have other positive features: they contribute to reducing the bloom of toxic algae in reservoirs in addition to saving land resources.

Ukraine, Romania. Cascade of the Danube and Dnipro lakes is considered promising for SPPs installation. According to preliminary calculations, they can place solar panels on an area of 600-700 km^2 (Fig.).

Fig. Example of solar panels placement: South Korean company Solkiss plans to install a floating solar power plant on the Deoku reservoir. The capacity of the power plant will be 2,67 MW

It does not really have analogues in the world. In this case, area is not so important. In this case, it is not so much the area that is important as their attractive indicators: wind, solar albedo, lake areas, and, most importantly, almost inexhaustible fresh water resources. Such SPPs are installed in the Danube cascade of Ukraine and Romania and can effectively interact with existing hydroelectric systems.

The proposed tandem of wind and solar energy would distribute energy generation throughout the day and ensure full functioning without possible temporal dependence. The proposed total area of the Danube region could be more than 1,000 km^2 of water surface and almost unlimited water resources of the Danube, which ultimately makes it possible to implement global energy projects that no other country has.

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SUBSTANTIATION OF NECESSITY OF RESOURCE OPTIMIZATION IN IRRIGATION IN THE CONTEXT OF MODERN CHANGING CONDITIONS AND REQUIREMENTS

Modern changing conditions and requirements related to global food, water and energy crises, which are exacerbated by threatening climate changes, demand the need to adapt to existing challenges and threats and increase the efficiency of all spheres of economic activity, including increasing the efficiency of agricultural production, primarily on reclaimed lands, which are kinds of guarantee fund for food security in our country and beyond. Russia's war against Ukraine showed how much our agricultural production affects the food security not only of Europe, but also of the whole world.

With the beginning of the full-scale war, the losses of cultivated areas in Ukraine, caused by the temporary occupation and military actions, amounted to more than 25% of the total fund, and the main part of these losses is highly productive irrigated lands, which give 2-3 times higher yields compared to rainfed lands. After the terrorist act of russia at the Kakhovka Dam, which led to further reduction of cultivated areas, the problem of shortage of water resources for irrigation reached a critical level, which is already relevant both at the regional and at the planetary levels.

In this regard, ensuring of food security in the conditions of a shortage of necessary resources requires increasing the efficiency of the functioning of irrigation systems, taking into account modern challenges, conditions and requirements, which demand, first of all, a change in methodological approaches to their creation and operation, which should be based on the resource approach.

New methodological approaches should be based not only on the assessment of the effectiveness of the adopted technical decisions, but also take into account the real operating conditions of the object, the level and direction of agricultural production, as well as, first of all, the amount of resources spent to ensure it. Therefore, the methods of creating and functioning of irrigation systems should provide optimization of project decision based on taking into account indicators of technical, ecological, economic and resource efficiency of the irrigation system functioning, which at this stage meets modern conditions and requirements. It is well known that irrigation is one of the most water and energy consuming branches of agriculture, which directly affects the economic and ecological effect of its implementation. At the same time, during the implementation of agricultural production on irrigated lands, in addition to the main ones - water and energy, this process involves a large number of other types of resources.

In this regard, the methodology of resource optimization should be based on minimizing the use of water and energy resources with the maximum effect from agricultural production, i.e. reducing the specific costs of resources per unit of agricultural production. The complexity of such a methodology lies in the need to take into account resources of different nature - water and electricity, which, in turn, are interconnected and mutually determining in their parameters.

In the development of our earlier studies, the substantiation of optimal solutions in the projects of construction, reconstruction and functioning of irrigation systems, as complex natural-technical ecological-economic systems, with this approach, can be performed according to a complex optimization model (Rokochynskyi, 2010), which in a general implicit form is the following

$$\begin{cases} U_0 = \underset{\{i\}}{extr}\, U_i, i = \overline{1, n_i}; \\ R_{0j} = \min\limits_{\{i\}} \left| R_{ji} - \widehat{R}_j \right|, j = \overline{1, n_j}; i = \overline{1, n_i}, \end{cases}$$

where U_0 - extreme value according to the accepted condition of the chosen criterion of economic optimality U, which corresponds to the optimal technical and technological solution according to the set of possible options $I = \{i\}$, $i = \overline{1, n_i}$; R_{ji} – a set $\{j\}$, $j = \overline{1, n_j}$ of resource use criteria for the relevant technical and technological solution options; $\widehat{R}_j$ - relevant reasonable indicators of the level of use of this resource.

The system of equations in a general implicit form allows, on the basis of resource optimization, to theoretically justify the possibility of setting a problem, searching, and consistently determining optimal regime, technological and technical solutions for heterogeneous constituent elements and the system as a whole in their relationship both empirically and empirically-functionally level of equal definition of the dependence between them. In order to achieve the goal of resource optimization – reducing the specific expenditures of resources per unit of agricultural production, the basis for improving irrigation techniques and regimes of irrigation of agricultural crops should be studied on the dependence of the amount of these expenditures and the obtained harvest, namely, that in the same year with different distribution of the same amount of irrigation water, it is possible to obtain significantly different harvests.

These provisions can be illustrated by the experimental data of the Bulgarian researchers Crafty G. and Kotov L. (Krafty & Kotov, 1970). They studied the effect of different irrigation regimes on the corn yield in the case of water shortage. To apply the entire irrigation rate, it was necessary to carry out three waterings with the same rates, this variant of irrigation was the control. For the control variant, waterings were carried out at the beginning, in the middle and at the end of the vegetation period. For studied different variants of irrigation one of the three waterings was successively cancelled. Despite the fact that these studies were carried out back in the 70 s of the last century, now this direction has not received the appropriate level of study and development due to the functional limitations of contemporary computer equipment and the lack of suitable mathematical models.

On the basis of a computer program (Koptiuk et al., 2022) developed in the research laboratory «Optimization and automation of management in water engineering and water technologies» at the department of Water Engineering and Water Technologies of the National University of Water Management and Nature Management (Rivne, Ukraine), were implemented a machine experiment, which actually reproduces the studies described in (Krafty & Kotov, 1970).

The computer program used to implement the machine experiment is based on the use of a set of

optimization, economic-mathematical and predictive-simulation methods and models, including models of climatic conditions of the area, of the water regime and water regulation technologies, as well as model of the yield of crops grown on reclaimed land for predictive assessment on a long-term basis of indicators and parameters of the technological, economic, environmental and investment efficiency of the object's functioning.

The application of these models is regulated by the relevant industry standards of the State Water Agency of Ukraine (Rokochynskyi et al., 2011; Rokochynskyi et al., 2006; Rokochynskyi et al., 2008).

Thus, modern conditions and requirements for conducting agricultural production make it necessary to change approaches to project decision-making in projects of construction, reconstruction and functioning of irrigation systems based on resource optimization, the purpose of which is to optimize the consumption of water and energy resources per unit of agricultural production, which will ensure an increase in the economic and ecological efficiency of the functioning of irrigation systems in accordance with modern conditions and requirements and the efficiency of agricultural production on irrigated lands as a whole.

The obtained results and the presence of a set of optimization, economic-mathematical and forecasting-simulation models create the necessary prerequisites for the improvement of crop irrigation regimes on the basis of resource optimization and optimization of water and energy use in general, as a necessary condition for increasing the efficiency of the functioning of irrigation systems in relation to modern changing conditions and requirements.

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FORECASTING AND SEARCH SYSTEM FOR AMBER IN UKRAINE: PURPOSE, STRUCTURE, IMPLEMENTATION

In recent years, Ukraine has been developing an «amber» branch of the economy that includes amber forecasting, prospecting, mining and processing [24]. Its development requires the expansion of its mineral resource base. This requires a scientifically sound, modern methodological basis for the "amber forecasting and prospecting system" (PPSA).

Purpose of the PPSA will allow the amber industry to develop systematically, addressing *environmental, socio-economic, scientific, educational*, and *educational* issues in a comprehensive manner.

Structure of the PPSA. The main *elements* of the PPSA at the level *of theory* are the "amber-bearing formation" (AF) and *practice* - "amber-bearing object" (AO).

The AF includes *theories of amber origin* and *scientific- methodical approaches* to its study.

According to *the known theories of amber origin*, it was formed in 3 stages. At *the first stage*, the oleoresin flowing from the tree took the form of a drop, formed clusters and growths that separated from the trunks and fell into the soil. The release of oleoresin could last for a long time, temporarily stop, and resume again. At *the second stage* lasted longer than the previous one - the hardened resin accumulated in forest soils and formed *soil-biogenic* deposits that are of little practical importance. At this stage, active resin *fossilization* took place. *The third stage* was the final one in the formation of amber, lasting the longest - thousands and millions of years. It began with the erosion of soils containing primary biogenic deposits of fossilized «amber forest» resin, which, along with derivatives of «amber forest» soils, was washed into river valleys and then into sea water. In the alkaline paleohydrochemical environment of the sea, with the participation of glauconite, the oxidized resin was converted into amber. In the alkaline paleohydrochemical environment of the sea, with the participation of glauconite, the oxidized resin was converted into amber. Its low specific gravity and high buoyancy contributed to the movement of amber over long distances, with little or no grinding or rolling. In the following geological epochs, amber was constantly redeposited. Starting from the Middle Eocene, a *materially-morphological body* AF appeared in the geomorpholithosphere, in which primary and repeated amber placers are stored.

At the same time, the AF, like all geological formations, is formed by the processes of *tectogenesis, morphogenesis, lithogenesis,* and *amber oreogenesis*, which interact *systematically*. As a result, tectonic (neotectonic) structures, landforms, sediments, and amber deposits are formed.

.*The main practical goal* of the PPSA is to identify «amber-bearing objects» (AO) - (traps) of placer amber deposits.

The studies of the factors of AF formation allow us to predict *structurally-tectonic, geomorphological, paleogeomorphological, morpholithogenetic* and *combined* types of amber traps.

The research of AF for the purpose of detecting AO is based on separate *scientific-methodical* approaches: *stratigraphic, lithological-stratigraphic, lithological, structural-tectonic, paleogeomorphological, geomorphological,* and in recent years - *geoecological*.

Implementation of the PPSA is a ***special amber prospecting map***, which is the goal and result of its implementation. The map contains all the collected direct and indirect data on the territory's AF, which are summarized and formalized. These data form separate "layers". It is important not to overload the map and, at the same time, not to lose the necessary information. The amber prospecting and exploration map is *analytical* and *synthetic* in terms of its generalization. Its *analytical* character is determined by data on the structure, structure and conditions of the AF development (stratigraphic, lithological, tectonic, geomorphological, paleogeomorphological).

The *synthetic* content of the map is shown by the defined taxa of its zoning, which are different at different stages of the development of the AF - *forecasting, prospecting, exploration*. Of course, the formalized map database is electronic. It contains a large array of information that is further generalized depending on the purpose and scale of the map.

The content of the map legend is determined by *direct* data related to amber-succinate and amber-like resins.

These are their various characteristics - individually and in clusters (size, color, fractions, content).

Secondary data relate to the structure, structure and factors that determine the development of BF. These are stratigraphic, lithological-stratigraphic, structural-tectonic, geomorphological, paleogeomorphological data.

These are the specific stratigraphic horizons of the Paleogene system (Charkiv, Mezhyhiria, Obukhiv strata), where the primary amber-succinate deposits are found.

This also includes the stratigraphic horizon of the *buchach svita* of the Middle Eocene, which, according to many researchers, is considered to be the original source for the formation of the AF of Western and Eastern Europe.

The map also shows the differentiation (zonation) of these horizons based on empirical data to identify lithological reservoirs of primary amber deposits. The structural and tectonic data cover the time of the BF formation.

These are tectonic (neotectonic) structures active in the Neogene-Quaternary period, both newly created and inherited from older morphostructures.

These structures determined the processes of litho- and morphogenesis from the beginning of the formation of amber-like resins (Middle Eocene), which were the basis for the formation of amber-succinite and its deposits (Late Eocene-Oligocene), subsequent erosion of deposits, redeposition of amber from them and formation of new placer deposits in the Neogene and Quaternary horizons.

Paleogeomorphological data relate to promising elements and forms of the ancient relief of the time of amber-succinate formation (Oligocene) and subsequent transformations.

The geomorphological data should reflect the modern understanding of "relief" as a "geomorphosystem" and its functional elements that directly affect the formation of amber accumulations.

The last information block of the amber prospecting map is the main one. It shows both prospective prospecting areas and specific amber-bearing objects (traps).

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COMPACT TECHNICAL MEAN OF REGULATING THE CONCENTRATION OF WATER OXYGEN IN THE SHALLOW WATER BODIES

The vast majority of water bodies in Ukraine have a limited depth, which does not exceed 5 to 7 meters [1]. Processes of succession and anthropogenic water pollution caused the decrease in water quality in most water bodies.

Prevention of the process of eutrophication in shallow water bodies has become an important ecological and economic problem of water resources policy in Ukraine. A reliable way to solve this issue is to develop technical solutions that ensure the regulation of the parameters of the state of the water area within the limits stipulated by the standards and prevent their eutrophication.

As the researchers have established, one of the effective ways to combat eutrophication is to saturate the water body with oxygen (i.e. aeration).

Oxygenation of the water body helps to slow down the process of eutrophication, reduce nitrogen compounds, which is one of the main nutrients in the emergence of the blooming of the water body [2].

But the effective use of conventional types of airlift-type aerators in shallow water areas is impractical due to their significant vertical dimensions.

So, the authors put forward a hypothesis and proposed a technical solution for reducing the size of airlift aerators and increasing their performance by creating a recirculation movement of water inside the unit.

Authors was proposed to improve the well-known aerator airlift for intensifying water oxygenation and overcoming the threat of its eutrophication by increasing the time of contact of air with water [3]. The improvement is that the recirculating aerator, which contains the airlift pipe section, the spray nozzle, the geothermal heat exchanger with filter and the compressed air line, additionally contains a closed outer housing with a flow regulator installed in its upper part and connected to the geothermal heat exchanger pipe with filter in its lower part.

Moreover, the airlift pipe section is installed inside the outer housing, and the air duct is equipped with a valve.

Thus, due to the recirculation of a portion of the fluid flow, a technical result is achieved, i.e. an increase in the oxygen concentration in the process of aeration of water due to an increase in the time of its contact with air bubbles.

Repeated return of a portion of the water flow to the airlift for oxygenation allows reducing the geometric dimensions of the unit without reducing the effective prevention of eutrophication of the water body.

The use of a recirculating aerator makes it possible to create an area of oxygenated water in a shallow water body without eutrophication conditions.

With the use of a recirculating aerator, it becomes possible to build units for the prevention of water eutrophication in shallow water bodies with minimal operational losses (Figure 1). The technology of water oxygenation using the proposed unit is as follows. The recirculating aerator is arranged at the bottom of the water body; it is a good practice to arrange it near the places where the fish are fed. A mast with a wind power generator is installed on the surface.

An air compressor acts as an electrical load, supplying compressed air via an air duct to a spray nozzle installed in the airlift.

The rate of water oxygenation is regulated by changing the air flow; it is also possible to control the value of the recirculation coefficient by increasing or decreasing the size of the orifice in the flow regulator.

Two features were taken into account for the unit operation. Due to the unevenness of the wind flow, e.g. in a calm, the power of the wind genera- tor may become insufficient to ensure the operation of the compressor.

In this case, the compressor is connected to the conventional power grid. This allows for continued aeration in adverse weather conditions.

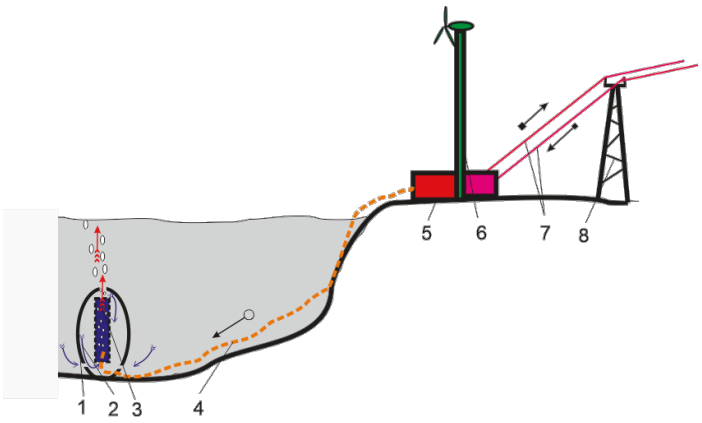

Fig. 1. Unit for water oxygenation using a recirculating aerator: *1* - outer housing of the aerator; *2* - flow of recirculating water; *3* - airlift column; *4* - duct; *5* - compressor; *6* - mast with wind generator; *7* - electric power grid; *8* - power grid mast

Thus, use a recirculating aerator with combined energy supply and the use of a 'green' tariff, allows for reducing operating costs, and in some cases, returning the capital costs and make a profit.

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USING PEAT FOR OBTAINING ALTERNATIVE ENERGY CARRIERS

The energy policy strategy of Ukraine stipulates the improvement of the structure of the fuel and energy balance, the development of new types of energy, the development and implementation of energy-saving technologies and equipment, and the rationalization of the fuel and electricity supply system.

The development of alternative energy based on the use of peat will satisfy the energy needs of the housing and communal services system and other enterprises. Improving the efficiency of energy supply includes:

- creation and development of new energy-saving technologies;

- improvement, reconstruction and technical rearmament of energy supply systems with heat and fuel with wide use of peat and decentralized systems;

- development and implementation of "small energy" systems and means mainly based on the use of local energy resources, renewable energy sources, combined systems and equipment;

- use of low-cost technologies for obtaining gas and liquid fuels from peat and other local biological raw materials, which meet international standards in terms of quality.

The use of peat as a fuel is due to its composition: high carbon content, low sulfur content, harmful non-combustible residues and impurities. In fact, this is young coal [1]. Peat resources of Ukraine are sufficient for their industrial use [2].

In solving this problem, an important role is assigned to the development and implementation of technologies and sets of equipment for processing peat into high-quality liquid and gaseous fuel (including the "quick pyrolysis" method).

Development and formation of "small energy" systems and means for autonomous energy supply of a number of enterprises and objects using local energy resources, renewable energy sources, plant and wood waste, development of new methods of processing biomass and peat, with the aim of obtaining high-quality liquid and gaseous fuel for use in the system of housing and communal services, as well as in other branches of economy, is an urgent issue and corresponds to the state development strategy of Ukraine. The technical rearmament of the heat and energy supply systems of facilities with the wide use of local fuels and decentralized systems has great prospects.

The basis for the production of alternative fuel is milled peat, which is extracted by the method of the same name at peat enterprises [3]. The main areas of activity of these enterprises are peat ex-

traction, production of peat briquettes for communal and household needs, organization and implementation of trade in peat products [4].

To ensure the production of alternative energy carriers from peat (generator gas, liquid fuel), a number of technological processes are performed:

- peat extraction;
- preparation of peat for loading into the gas generator;
- obtaining generator (synthetic) gas.

During the gasification process, peat undergoes several transformations that form four separate zones: the drying zone, the pyrolysis zone, the burning zone, and the recovery zone. Depending on the direction of movement of fuel and products of chemical reactions in these zones, direct and reverse gasification processes are distinguished. Both processes have their advantages and disadvantages. The direct process imposes almost no restrictions on the appearance and moisture content of the fuel, but the resulting gas is very dirty and contains a large amount of pyrolysis resins. Gas purification for use in internal combustion engines requires complex and expensive purification systems with catalytic cracking of resins. The reverse process imposes restrictions on the moisture content of the fuel, which necessitates additional preparation of the fuel, but ensures the production of clean generator gas with a minimum content of pyrolysis resins.

In the drying zone, the heat from the lower parts of the gas generator causes water to evaporate, due to which the fuel is dried at a temperature of 150-200 °C. Water vapor moves down and is added to the water vapor formed in the combustion (oxidation) zone. Part of the water vapor can be reduced to hydrogen, and the rest is released as moisture in the gas.

Below the drying zone, the temperature increases to 400-650 °C. At a temperature above 250 °C, the process of fuel pyrolysis begins. The details of the chemical reactions of the pyrolysis process are not very well known, but it is assumed that when heated, large molecules such as cellulose, hemicellulose and lignin are broken down into medium molecules and carbon (charcoal). The pyrolysis products move down into the hot zones of the gas generator. Some of them burn into combustion zones, others break down further into even smaller molecules, such as hydrogen, methane, carbon monoxide, ethane, ethylene, etc., if they stay in the hot zone long enough.

The combustion (oxidation) zone is formed at the level of air intake. Reactions with oxygen are highly exothermic, resulting in a sharp increase in temperature to 900-1200 °C. An important function of the oxidation zone, in addition to heat generation, is the transformation and, if possible, the complete combustion of all condensed products, which, in the case of their condensation in the low-temperature parts of the system, turn into pyrolysis resins and oils. Air is supplied to the combustion zone using several tubes located around the combustion cone.

The reaction products in the oxidation zone (hot gases and hot charcoal) move down into the reduction zone. In this zone, the heat retention of gases is transformed into the chemical energy of the generator gas. The final products of chemical reactions occurring in the recovery zone are combustible gas with a temperature of 250-500 °C, which can be used as fuel gas in burners, and after cleaning from fly ash and additional cooling - in internal combustion engines.

The technology of production of generator gas from peat is waste-free production without harmful emissions. This technology improves people's social and economic living conditions.

The development and implementation of "small energy" systems and means based on the use of traditional types of fuel, renewable energy sources, and local energy resources is an important addition to centralized energy supply, and for a number of objects it can become the main one. This will make it possible to provide heat and save traditional purchased energy resources when using combined units for energy saving for a number of consumers.

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ACTUAL PROBLEMS OF DISTURBED LANDS RECLAMATION DURING AMBER MINING IN POLISSIA

The problem of illegal amber mining in the forest lands of Ukrainian Polissia (Volyn, Rivne, and Zhytomyr regions) has existed for more than 16 years, but it became a particularly relevant subject of public attention in 2016-2017, primarily thanks to the efforts of the public and mass media.

The illegal activity of unauthorized amber mining causes serious economic losses to the state and society, is accompanied by the deterioration of the social climate, leads to the degradation of large areas of forest land, and the deterioration of the ecological situation. Since disturbed biotopes cannot be restored to their original state naturally, without human intervention, they require reclamation.

One of the areas of intervention in the situation by state bodies and the public is the practical implementation of the rehabilitation of disturbed areas. For this purpose, the Cabinet of Ministers adopted Resolution №1063 dated November 30, 2016, which approved the "Procedure for the implementation of the pilot project for the reclamation of forestry lands disturbed as a result of illegal amber mining." According to this resolution, the order of the State Forestry Agency of Ukraine № 138 dated 21.04.2017 established the "List of forestry lands, within which there are parts disturbed due to illegal amber mining and in need of reclamation", which included 2,046 disturbed plots with a total area of 30,037.6 a hectare Therefore, the issue of reclamation of disturbed lands as a result of illegal amber mining is undeniably relevant.

Illegal mining is uncontrolled, and not only in terms of the volume of extracted raw materials, but also in terms of the consequences of mining - violation of natural territories. Nature is a complex system where all components are inextricably linked to each other. Therefore, the disturbance of the geological environment inevitably causes negative changes in the adjacent environments. At the same time, the biotic component of nature is most negatively affected [1].

During the extraction of amber by mining, the grass and shrub layers of the forest are completely destroyed, the root system of trees is mechanically damaged, and in frequent cases, trees are cut down and uprooted. Due to lack of soil and due to damage, the root system is not able to keep the trunk in a vertical state and the trees bend or even fall under their own weight. At the same time, neighboring plants can be damaged, the undergrowth dies. Over time, most trees die. Such territories are characterized by an almost complete absence of primary soil cover, instead, a huge number of pits sharply reduces the area for the development of seeds, and therefore, young forest. In this way, the modern forest is destroyed and the conditions for its restoration are not created [2].

It has been established that the plant communities that spontaneously and slowly develop on disturbed areas differ from the original phytocenoses. In addition, the drainage ditches significantly disrupt the hydrological regime, the territory dries out, which leads to the weakening of tree stands, their loss of ecological stability and the negative dynamics of vegetation. Taking this into account, it is necessary to carry out continuous reclamation of areas disturbed by illegal amber mining [3].

Research has established that the reclamation of disturbed lands should be carried out in a complex manner with research and industrial development for the complete extraction of amber, in order to protect the reclaimed lands from unauthorized actions in the future. Thus, the removal of forest remnants and the full development of areas in an open manner is a necessary stage of reclamation work. After the completion of research and industrial development and technical reclamation, it is

necessary to carry out an additional ecological and economic assessment of the disturbed areas with the aim of additional extraction of amber, forest plantations and use for agricultural production [4].

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RESEARCH OF THE AMBER MINING MACHINES AUTOMATION COMPLEX

The issue of amber extraction from amber-bearing deposits and its additional extraction from areas disturbed as a result of illegal activity is of considerable interest. Solving this issue will bring economic benefits to the united territorial communities. It will also allow for final reclamation with the possibility of agricultural activity [1, 2].

The site's electromechanical equipment unit for automating the amber mining process is a complex complex of mining ("technological") and transport machines (Fig. 1).

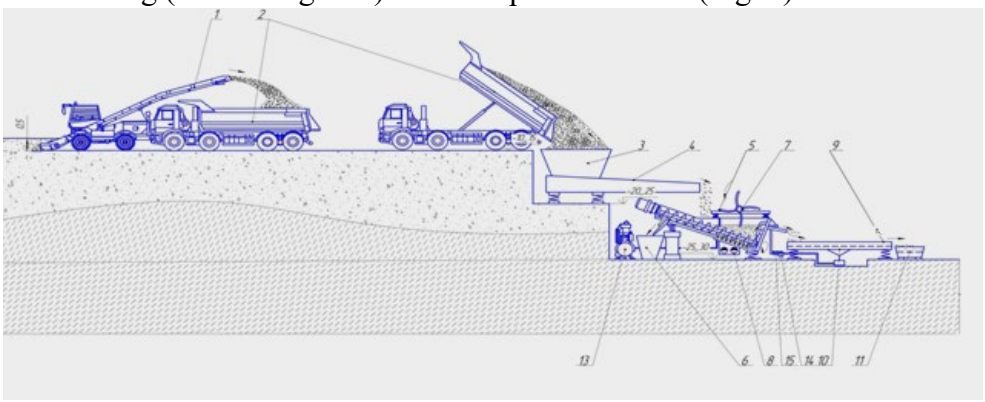

Fig. 1. Technological scheme of layer-by-layer processing of sand-clay amber-containing raw materials: *1* - raw material loader; *2* - transport elements of raw material delivery; 3 - bunker; *4* - vibratory feeder; *5* - vibration classifier; *6* - bunker; *7* - blade grippers; *8* - vibrator; *9* - screen; *10* - drain; *11* - bath for classification with salt solution; *12* - excavation works using a bulldozer; *13* - compressor; *14* - filter; *15* - pump

The technology of carrying out the work involves excavation work with bulldozer equipment (not shown in Fig. 1) before the start of mining operations. Mineral extraction is carried out by the mining unit (loader of raw materials *1*) in layers with loading into transport elements *2* to deliver the mining mass to the place of processing, which is represented by the receiving hopper *3* with a vibratory feeder. The vibrating feeder *4* supplies raw materials to the vibrating classifier *5* in a dosed manner with a uniform supply of mining mass and water. The material in the form of pulp is fed into the cavity formed by the casing using a loading device, where it is mixed under the action of a screw and a vibrator. The vibration classifier is equipped with an automated control system. Qualitative classification and maximum extraction takes place in a bath with salt solution *11* [3, 4].

A technological scheme with a complex of equipment and machines is mutually related: a deterioration in the performance of some machines leads to a decrease in the productivity of others related to them, and therefore, a deterioration in the operation of the entire complex. To ensure constant mutual communication of the machines that are part of the electromechanical complex, as well as to maintain the optimal modes of each of them that is part of the machine complex, their automation means are used. Automation of complexes and individual machines helps to increase their productivity, in addition, facilitates their management, increases the reliability and safety of work [5].

The use of means of automatic regulation of the supply of cars to potholes facilitates and rationalizes the dispatcher's work, makes it possible to reduce idle time and increase the speed of vehicle movement. On conveyor transport, automation performs the functions of remote control of conveyors, control over their operation and regulation of the operation of the electric drive.

Since the conveyor complexes work sequentially and in parallel, mutual automatic blocking of their operation takes on special importance.

Among the automatic devices that regulate and increase the reliability of conveyors, we can mention automatic adjustment of tensioning devices, automatic control of loading, overloading and unloading points, automatic adjustment of belt speed depending on the amount of material entering the conveyor and automation of a number of other transport and auxiliary processes.

In all cases of the use of appropriate means of automation, if they themselves do not introduce complications into the process and electromechanical equipment of pits, do not require additional operations to maintain them in working condition, the overall efficiency of the complexes increases significantly. At the same time, the task of establishing a rational degree (depth) of automation must be solved in each individual case.

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SUPPORTING OF THE ROADWAYS TO BE PRESERVED AFTER THE STOPE DRIVAGE

Supporting of roadways is of great scientific and practical interest [1-3], especially if they are preserved for reuse [4-6]. In this work, three supporting schemes were considered: with frames, rock bolt-frame support (fig. 1) and rock bolt-frame support reinforced with cable bolts (fig. 2). A numerical calculation of the stress field in host rocks in the zone of intersection of the roadway and the stope was completed, for the analysis of which the following parameters were used [7] $Q^*=(\sigma_1-\sigma_3)/\gamma H$ and $P^*=\sigma_3/\gamma H$ (σ_1, σ_3 - maximum and minimum components of the principal stress tensor, Pa; γ – averaged weight of the overlying rocks, N/m^3; H - the mining depth, m).

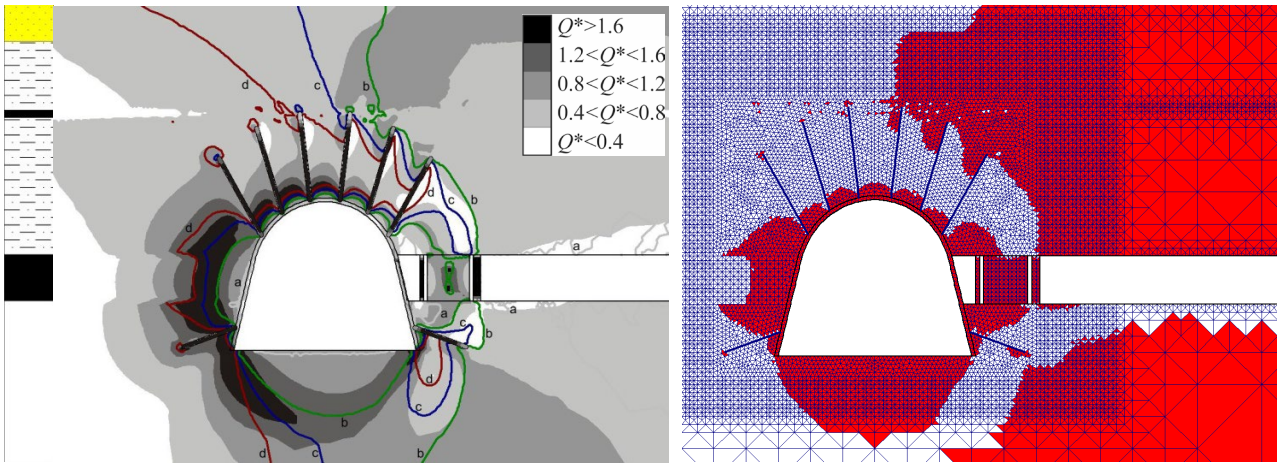

Fig. 1. Distribution of Q^* and P^* parameters values: *a* - P^*= 0,1; *b* - P^*= 0,2; *c* - P^*= 0,4; *d* - P^*= 0,6 (left side); zones of inelastic deformations (right side), rock bolt-frame support

A rock-bolts arch [8] is formed in the mine roof, which preserves its integrity even after the stope drivage (fig. 1). However, destruction of the left wall of the roadway will lead to lowering of

the rock-bolts arch into the roadway. To prevent this, installation of additional posts or the use of cable bolts is required.

When cable bolts are used, the area in the mine roof where $0,8<Q^*<1,2$ is significantly reduced (fig. 2, left side), which diminishes the risk of the rock-bolts arch collapse. The load on the left wall of the roadway decreases, as well as the area of inelastic deformations above the rock-bolts arch (fig. 2, right side).

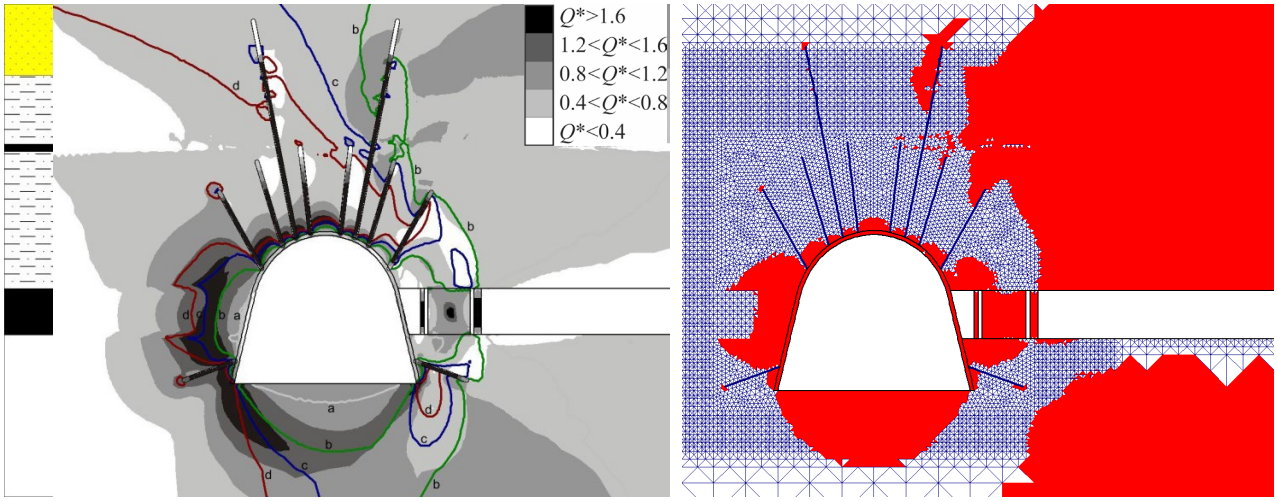

Fig. 2. Distribution of Q^* and P^* parameters values: *a* - P^*= 0,1; *b* - P^*= 0,2; *c* – P^*= 0,4; *d* - P^*= 0,6 (left side); zones of inelastic deformations (right side), rock bolt-frame support with cable bolts

When using frame support, stoping operations can lead to the collapse of fractured host rocks and to a critical increase in Q^* parameter values in the left wall of the roadway. When using rock bolt-frame support, a rock-bolts arch is formed in the mine roof, and after the stope drivage, the load-bearing arch remains in a working condition. However, in case of unstable host rocks or presence of a weak rock bed in the main roof of the roadway, there is a risk of the bolted arch lowering. Therefore, deep cable bolts are used as reinforcement support, making it possible to connect the load-bearing arch with undisturbed rocks deep in the massif.

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ASSESSMENT OF THE EFFECTIVITY OF THE CURRENT DE-WATERING BOREHOLES DRAW-DOWN ON THE FINAL BENCH AT NCHANGA OPEN PIT MINE, ZAMBIA

Abstract

Nchanga Open Pit is the second largest open pit mine in the world, located in the municipal town of Chingola in the Copperbelt Province of Zambia. There are currently two active open pits, namely “CUT 2” and “COP F&D”.

The primary problem at the COP F&D is groundwater accumulation at the pit bottom due to seepage through the sideways. The main cause of seepage is the intersection of the water table with the major aquifers which are the Chingola Dolomite, Upper Banded Sandstone, Lower Banded Sandstone and Upper Roan Dolomite.

The mine has a dewatering system in place of vertical dewatering boreholes that have been sunk from surface and the sacrificial boreholes in the pit. However, in the recent past the number of operational boreholes have been fluctuating which makes it difficult to maintain a good draw down.

The purpose of this study is to determine the optimum number of dewatering boreholes required for effective drawdown so as to keep the final bench below the water table. The study applied construction observations and field measurements method (pumped flow rates and groundwater drawdown levels) to re-design and refine the dewatering system.

The observational method was used because it focuses on records of the amount of water pumped, flow rate and drawdown levels.

The data collection was split into two categories: primary data from field observations and secondary data from company records. Empirical data on levels of the water table was obtained from piezometer readings from observation wells.

These devices use sensors to indicate the presence of water and built-in measuring tapes to measure the depth of water periodically. Results of study indicate that the causes of failure to meet

planned targets of operational boreholes and sump pumping in specified periods was due to flaws in running of the dewatering pumps 24/7, destruction and displacement of borehole pipes due to activities such as drilling, blasting, loading and hauling.

In order to bridge the gap between the amount of water that accumulates in the pit and the water that is pumped through the boreholes and sumps at COP F&D, it is recommended that twenty two (22) bores be installed and the dewatered volumes be discharged at a more distant location far from the pit perimeter to avoid recharge of water in the permeable formation which is too close to the pit parameter.

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ASSOCIATED MINING OF MINERAL AND RAW MATERIAL RESOURCES FROM COAL MINES IN THE WESTERN DONBAS (UKRAINE)

In the modern world, issues of mining and processing of mineral resources play an important role in the economic development of countries in the context of problems of sustainable development, environmental protection and social responsibility.

In order to address these pressing issues, it is necessary to create a concept for complex mining and processing of mineral and raw material resources, based on scientific-theoretical principles and modernization of existing technologies with a parallel transition to multiproduct production.

Using the example of the Western Donbas mines (Ukraine), the authors propose the idea of transitioning single-product coal production to the creation of multi-vector mine complexes capable

of producing electricity, heat, clean drinking water and associated mineral and raw material resources for various types of industry.

The model components of a complex for mining mineral and raw material resources from coal mines are as follows (see Fig. 1):

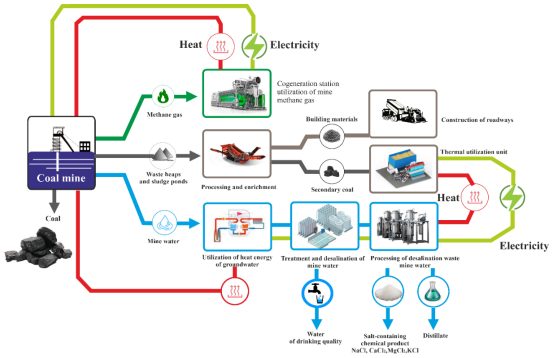

Fig. 1. Model for complex mining of mineral and raw material resources from coal mines

- mine complex for mining coal seams within the boundaries of a designated mine field;

- the cogeneration station complex for the mine gas methane utilization is an additional energy source for covering the thermal and electrical loads of the mine complex consumers while simultaneously reducing greenhouse gas emissions, that is, reducing the burden on the environment of the mining region. The generated electricity is aimed at supplying the enterprise's own consumers, and the excess energy can be sold to the domestic energy market;

- groundwater energy utilization complex to meet the hot water supply needs of the mine;

- sludge disposal complex with electricity generation;

- waste rock dump processing complex;

- mine water demineralization complex with processing of desalination waste for production of drinking water, distillate, dry salt-containing chemical products.

Detailed research and development of model components for complex mining of mineral and raw material resources are presented for the mining-geological conditions of the PJSC "DTEK Pavlohradvuhillia" mines, since it is an important link in the energy security chain, providing 81,8% of the thermal coal production in Ukraine.

A gradual transition to mining of associated mineral and raw material resources at coal enterprises that complete the exploitation of coal reserves and are scheduled for closure will avoid social, economic and environmental consequences.

The conducted research is an integral part of the "Energy Strategy of Ukraine until 2050", which provides for achieving carbon neutrality in the energy sector through the development of renewable energy sources, hydrogen energy, support for scientific research and development of industrial technologies in the field of waste recycling.

Steps have been developed to transform the coal mines of the PJSC "DTEK Pavlohradvuhillia"

company with the gradual diversification of production to produce “green” hydrogen, alternative energy sources, processing coal mining waste to obtain synthesis gas, rare metals - germanium, scandium, gallium, etc. for the development of high technologies.

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CONTROL SYSTEM OF THE HYDROMONITOR WASHING PROCESS

A review of the existing systems showed an insufficient level of automation of the technological process of hydromonitor washing. The control of erosion is mainly carried out by the operator, which does not ensure the necessary quality of management and productivity.

We propose to control the process of hydromonitor erosion based on the control of the distance between the hydromonitor nozzle and the wall of the pit and the rate of rock erosion. Monitoring the change in dimensions of the extraction chamber over time also provides information on the performance of the washing process [1].

The efficiency of erosion is determined by the performance of the hydromonitor and the specific energy capacity, which depend on the parameters of the stream, the physical and mechanical properties and structure of the mined mineral, the magnitude of the forces and pressures in contact with the outcrop, and the technological methods of rock erosion .

The controlling influences in hydromonitor flushing are the pressure and consumption of the working agent (water), the speed of rotation and movement of the telescopic hydromonitor nozzle in the pothole .

The results of experimental studies of the dynamics of rock destruction when a water jet acts on it are shown in fig. 1 [2].

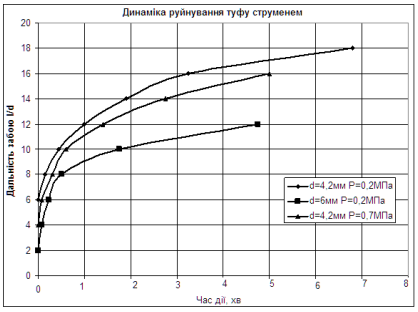

Fig. 1. Dynamics of destruction of tuff rock

It can be seen from the figure that with small distances between the nozzle of the hydromonitor and the wall of the hole, rapid destruction of the rock occurs. As the distance between them increas-

es, the pressure on the wall of the hole decreases, and when a critical value is reached, the destruction of the rock stops.

As a result of the analysis of the differential equations that describe the dependencies shown in Fig. 1, it can be concluded that the hydraulic washing process is a complex object, in which the parameters K - the transmission coefficient, $T(l_{ro}, P)$ - the time constant depend on the conditions of the process (pressure in the nozzle, physical and mechanical parameters of the rock, medium of jet movement, distance from the nozzle to the hole wall, shape and dimensions of the nozzle, etc.) and are determined from experimental data [1, 3].

Through modeling in the MatLab/Simulink package, transient characteristics of the object in terms of distance and erosion speed were obtained (Fig. 2).

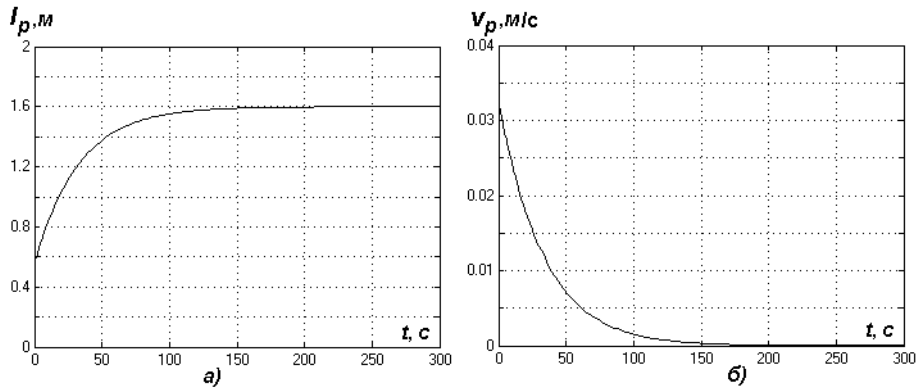

Fig. 2. *a* - Transient characteristics of the object in the distance of erosion;
b - Transient characteristics of the object in terms of erosion speed

The structural diagram of the simulation of the washing speed control system looks like this [1, 4, 5]:

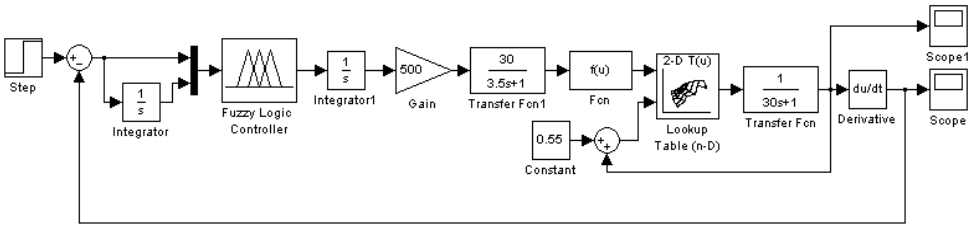

Fig. 3. Mathematical model of the washing speed control system

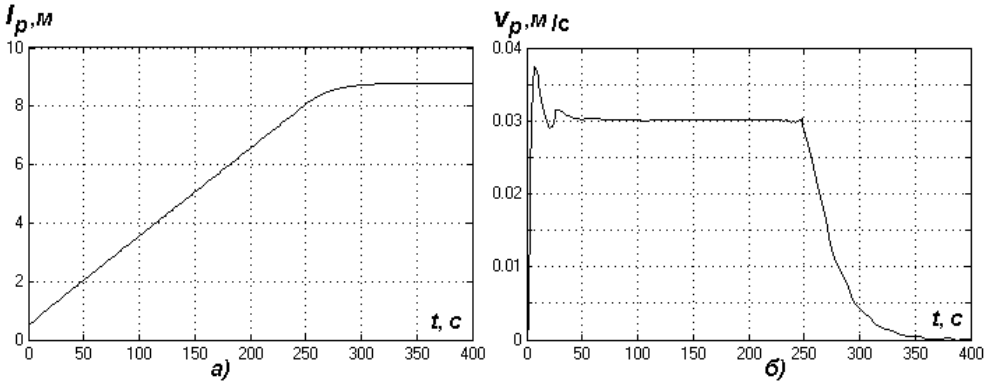

Fig. 4. *a* - Transient characteristics of SAR in terms of erosion distance;
b - Transient characteristics of SAR in terms of erosion rate

The organization of the control process by the speed and distance of washing will ensure reliable and effective control over the process of hydromonitor washing.

The developed mathematical model of the object can be the basis for designing flexible control systems for the hydromonitoring erosion process using adaptive, extreme, self-adjusting and fuzzy control methods, which will allow them to be used for the extraction of various minerals.

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USING A FLOATING CEILING TO IMPROVE ORE EXTRACTION

A mandatory requirement for the comprehensive development of mineral deposits is the most complete extraction of minerals from the subsoil. Consequently, the issues of reducing losses and dilution during the development of ore deposits remain relevant.

The Krivoy Rog iron ore basin is a unique deposit with huge reserves of iron ore. Most of the deposit is mined using caving systems for ore and host rocks. Such technologies predetermine large losses and dilution of mineral resources.

As the level of mining decreases, rock pressure increases and mining conditions worsen. This predetermines the need to introduce new technologies and technical means.

In recent years, scientific research has been actively carried out on a technology that will significantly improve ore extraction rates. Considering that the main problem area is the upper ore-rock contact, it is necessary to reduce the influence of this contact during ore release. This can be achieved by creating an artificial or natural overlap located at this contact.

Three options for such overlap are considered in the scientific literature:

- a protective layer of over-crushed ore at the ore-rock contact;
- flexible metal ceiling;
- an overlap made of a rock or ore monolithic block, cut from the hanging wall rocks at the ore-rock contact.

To determine the effectiveness of the protective layer of re-crushed ore, studies were carried out that considered the option of a sub-level caving system with diamond-shaped panels with a protective layer of re-crushed ore [1].

The influence of four technological parameters was analyzed: the granulometric composition of the overlying waste rock, the thickness of the over-crushed ore layer, the coefficient of primary loosening of the ore and the height of the produced ore layer.

Research has shown that ore dilution depends mainly on the ratio of the granular composition of waste rock, the thickness of the over-crushed layer, as well as the coefficient of primary loosening of the ore and is almost independent of the height of the produced layer. With an equal ratio of the diameter of a piece of the re-ground layer, dilution begins after the release of 32% of pure ore and reaches 59% when 74% of the ore mass is extracted. When the ratio of the diameter of the average piece increases to 0,5, dilution begins after the release of 89 and 96% of pure ore, while the di-

lution is 9 and 4%, respectively. And with an increase in the thickness of the protective layer of over-crushed ore, the loss of ore in the block is significantly reduced [2].

The development of the theory of protective overlap was the technology with flexible overlap. In this case, the block is processed in two stages [3].

At the first stage, a protective covering is formed in the form of a flexible metal shield made of strip iron. The second stage included work related to the excavation of all cuttings and the carrying out of clearing work. Due to the significant labor costs and long installation time of the flexible metal ceiling, and the impossibility of dismantling it after completion of the block, this option has not found proper application.

The most promising is the use of a “floating” ceiling, cut from the hanging wall rock mass by fans of deep wells. With a sufficient thickness of the ceiling, after the destruction of the ore mass and the sections of the ceiling from the rock mass, its integrity is preserved and the ability to perform the functions of a protective ceiling for the entire period of mining of the block [4].

Sublevel mining and floor release of ore through the outlet workings allows you to adjust the size of the exposure of the “floating” ceiling, intensify the release process, move the ore to the outlet workings through the use of gravitational forces, reduce delivery costs by 2 times and the share of preparatory cutting work by 2,5-3 times [5].

Mining steeply dipping ore deposits using a system with a “floating” ceiling has its own characteristics. A problem can be uneven lowering and overturning of the ceiling in the cleaning space. For stable movement in the clearing space, the “floating” ceiling is made with a height no less than the thickness of the mineral deposit and can have thickenings in the middle part, forming a body of equal resistance to movement [6].

Another way to ensure uniform lowering of the ceiling is to leave a temporary ore pillar, which will ensure that the ceiling is given a horizontal position [7,8].

Thus, the overlap, cut off from the rock mass of the hanging wall, will significantly improve the extraction of minerals and ensure comprehensive development of the deposit.

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THE CONTROL SOLUTION FOR WEAK ROOF IN THE FULLY MECHANIZED MINING LONGWALLS IN QUANGNINH COALFIELD, VIETNAM

The phenomenon of roof falling of the weak roof rock in the fully mechanized longwall is one of the main reasons affecting on the safety and efficiency of longwall mining process. Therefore, the analysis of causes for the phenomenon of roof falling in order to find out the proper preventive solutions, strengthen the roof control, reduce the falling roof accidents is very essential.

Regarding to the real issues in the work of coal mining and work of roof control, the authors researched and analyzed the main reasons leading to collapse of the roof rock near the face in the fully mechanized longwall and proposed solutions to prevent roof, contribute to the management and control of the weak roof rock reasonably.

The basic of controlling roof rock in the fully mechanized longwall is to control and protect the roof rock near a longwall face, because the roof rock near the longwall face above shield, basically it is not supporting area and the roof rock area are cracked, soft rock which belongs to the roof rock which are controlled in the mining longwall. At the area, combining just has moved past to mining in the immediate the roof rock are exposed and strain state also changed dramatically. However the shield has not moved forward promptly to support the roof rock here. If the roof rock in the area is type of soft and loose rock, it will tend to fall in space of the longwall, there will have the roof convergence. This issue causes the failures in the longwall and many difficulties of support works even though it may cause of the accident to the work.

During the coal mining process at the longwall faces, the roof rock is exposed immediately, at the same time the stress state here also changes drastically. But now, the shield still has not timely moved forward to hold roof rock near to the face. If it is weak and loose rock, it tends to fall to

space in the face, this problem can cause accidents in the face, besides it causes difficult to the holding work and unsafe for people working in mine.

Factors affecting the roof falling phenomenon in the longwall

+ *Factors of geology*

The geological factors such as folds, faults, fissures, cracks of coal and rock, strength of coal and rock etc. They are the factors affecting the stability of the roof rock. During the coal mining process at the longwall faces, structural dynamics of initial stability rock and coal are destroyed, the strain of the roof rock through coal seam to the floor rock. If coal is soft and breakable, the strain will fully transfer to the floor rock, leading to the roof rocks crumbling. The crevices and density of crack are the main factors determining the strength of the block rock. the crevices and cracks are more increasable, character of rock is more weakly and the strength of the rock is decreased, which makes the rock easily collapse. The geological fractures such as folds, faults, are easily formed. The rocks which are crumbled, easily to collapse. The angle between a longwall and the crumble of rock area issmaller, exposure area of the crumble of rock is larger that may result on the increase of the roof falling phenomenon to the longwall mining. The crevices and cracks are similar characters of rock swelling. The roof rock is weaker, the roof falling phenomenon is more sharply [1-3].

+ *The width exposure of the roof rock* [4]

After the shearer has cut coal, the roof is exposed. If the shield does not move in time to support the roof or during the move, the shield does not lower to the required level but still makes certain contact with the roof, reducing the support quality of the shield. The distance from the shield to the longwall face exceeds the specified value, which causes the exposed distance of the roof to be large, and then leads to the hanging time exceeding the specified time limit. The working load and initial holding force of the shield do not reach the specified value, or the mining height is greater than the maximum support height of the shield, resulting in pressure on a large area concentrated on the roof, which causes the roof to bend and creates problems with the phenomenon of face spall and roof falling.

During the coal mining process at the longwall faces, the roof rock is exposed. The width of exposure of the roof rock is larger, degree of collapse is higher.

In fact, the mining process shows that in case of distance exposure of the roof rock is zero (beam was closer to the longwall face) but the roof falling phenomenon still happened. The demonstration shows that the distance exposure of the roof rock is not the only the factor affecting the roof falling phenomenon which also involves many other factors.

+ *Initial support load of shield* [5]

During the operation of the shield, it is necessary to adjust the average working load of the shield to a reasonable level, which can reduce the problem of roof falling of the roof. In order to ensure the supporting load of the shield, it is necessary to first determine the initial support load of

the shield, but in fact, it is shown that the reasonable ratio of the initial supporting load of the shield is to be determined only about 70% on average, due to the following main reasons:

- the time to supply lubricant to the shield is short, the initial support load has not been achieved but the lubricant has stopped pumping;

- the pressure of the pump station is not enough, the valve and the pipeline are leaking;

- the floor is soft and weak.

The control methods for the weak and loose roof [6-8].

+ *Selection of reasonable shield*

The roof rock is instable, we selected beam of shield with the function of telescopic. During the coal mining process, we need to move shield closer to the longwall face following movement of the coal cutting shearer, support the roof rock after that it is exposed concurrently to pull beam forward, ensuring the smallest distance from the face to the beam. If the face is failed, it can be moved the beams to location of the face failures, immediately support before. This is also effective in the management of the weak and loose roof.

+ *Spread out steel grating under roof rock*

The weak and loose roof above the beam of the shield are crumble. Therefore, forming unstable rock layers with different thickness above the beam. So, when pulling the shield, this rock layers can fall down the gap between beam and the face which lead to the roof convergence phenomena on the increase. When spreading out the steel grating under roof rock, this makes the weak and loose roof from rock layer stable. Improving the support of the roof rock. Normally, spreading out the steel grating, two layers for managing roof rock have the advantages:

- Effective prevention on the roof rocks falling on among distance from the shield to the face. While improving the state's exposed roof rock and beams of shield.

- Effective improving the average load of the shield and rock hardness

- Effective for the prevention of the roof convergence phenomena, reducing the depth of the roof convergence phenomena.

+ *Adjusting and moving the shield closer with roof rock*

With the weak, loose and unstable roof lowering and moving the shield is normally very difficult. This time is necessary to apply the method to move the shield closed to the face. (when moving the shield, firstly starting the hydraulic jack, then gradually unloading to make loads of beams and roof rock certain ensure, then movinge the shield). Thus, the roof rock can’t appear the phenomenon of sudden instability. it will not only be effective roof control but also the shield move fast, reducing time of the hollow roof.

+ *Build up valve to ensure the initial load of the shield*

When workers perform movements of the shield, to improve movement speed, normally, the time to feed liquid for the shield must be short. Strength of initial shield is not enough so it is re-

quired to build valve to ensure the shield to continue the pressurization until achieving the strength of initial shield.

Conclusion

In the fully mechanized longwall with the weak roof rock, the roof control is fine, which lead to the decrease on effective work of equipment in the longwall and even threaten the safety conditions of workers. The authors summarize some of the actual production methods to handle the problem. This may be effective in the longwall mining with the weak roof rock.

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SOME FUNCTIONAL FEATURES OF THE USE DRILLING FLUIDS DURING THE CONSTRUCTION OF WELLS

If we do not take into account some exceptions, we can say the following. The process of drilling wells cannot be carried out without circulation of drilling fluids [1]. The purpose of drilling fluids is varied. Drilling fluids help reduce the hardness of rocks at the bottom of the well. They cool the rock cutting tool and bring the destroyed rock to the surface. Drilling fluids are the hydraulic power source for downhole motors. The presence of special substances in drilling fluids helps reduce power costs, which is associated with overcoming friction forces in the well. Further development of drilling technology requires the development and implementation of the latest well flushing techniques and drilling fluids formulations. In most cases, they allow you to avoid serious compli-

cations in the well. Such complications include violation of the integrity of the wellbore walls. The drilling fluids used should not have a high price (although they contain a number of scarce components). For them, it is necessary to provide for relatively simple and effective regeneration work. This will significantly reduce the cost of organizing the well cleaning process. Also, such conditions will contribute to compliance with environmental standards that prevent the release of harmful chemical compounds into the environment [2].

Reasonable regulation of the physicochemical properties of drilling fluids allows one to significantly rationalize the well construction process. Using this approach, it is possible to obtain a sufficiently long period of the wellbore being open. According to this method, it will be possible to avoid unreasonable costs for the additional use of expensive metal casing columns [3].

A rather interesting direction in the development of improving well cleaning technology is the use of surfactants. Among their fairly large number of advantages, several main ones can be highlighted [4]. The introduction of surfactants into the composition of washing liquids can significantly reduce their surface tension. This phenomenon will contribute to more active penetration of drilling fluids into the destruction zone. This will be the reason for improving the working conditions of drilling tools at the bottom of the well. An important reason for the need to use surfactants can be considered their noticeable effect on the cooling processes of the drilling tool, the removal of destroyed rock from the bottom, reducing the abrasive effect of rocks on the drill bit, reducing the power consumption for rotating the drill string (this happens by reducing the contact friction coefficient) [5].

In accordance with data from previous studies, as well as the conclusions of the authors, the lubricating, cooling and anti-corrosion effect of surfactants is based on the formation of films in the contact zone of interacting surfaces. In these zones, the polar molecules of the drilling fluids are adsorbed on the surface of the solid. Due to this phenomenon, the free surface energy decreases and active layers are formed, which, for example, significantly reduce the friction force. A reduction in friction, under the influence of the presence of surfactants, occurs through the formation of boundary phases that facilitate the mutual sliding of surfaces. According to the studies that were carried out by the authors of the present work, it can be argued that when up to 1.5% and slightly higher emulsol surfactant is introduced into the clay drilling fluids, a film is formed on the surface of the rock sample. This is the reason for reducing the friction coefficient and reducing power consumption for rotating the drill string in the well. Thus, a concentration of 1.5% is sufficient to effectively reduce the coefficient of friction (fig. 1).

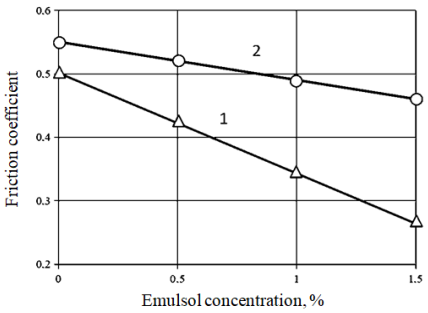

Fig. 1. Dependence of the friction coefficient on the emulsol concentration: *1* - clay drilling fluid; *2* - industrial water

Thus, it can be argued that there is a need for additional research in several directions [6]. Flushing fluids are an important factor in the ability to increase the productivity of the well drilling process. By reasonable regulation of the technological properties of flushing fluids, a significant reduction in capital costs for well construction can be achieved. The above will contribute to the intensification of work on the search, exploration and exploitation of mineral deposits.

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NEW TECHNOLOGIES FOR SECTIONAL ENTRIES DRIVING AND MAINTAINING AT "KRASNOLIMANSKA" COAL MINE

"Krasnolimanska" coal mine is located near the town of Rodynske in Pokrovsk district. Despite the proximity to the combat zone, the company carries out mining operations on the m_4^2 seam and preparatory work on the promising k_5 seam, which is 2,5 meters thick. Given the systemic shortage

of special interchangeable SVP22, 27, 33 profiles manufactured at Azovstal's Mariupol Iron and Steel Works, the company decided to switch crushed rockto anchor fastening [1] of new sectional entries with an additional shotcrete layer containing .

To increase the speed of driving and mechanize the installation of anchor bolts, two modern

Chinese EBZ160JM roadheaders (Fig. 1) with auto-anchor installers were purchase to replace the obsolete KSP-32 roadheaders.

Fig. 1. EBZ160JM roadheader with two auto-anchor installers

They drill anchor holes and install bolts along the contour twice as fast as the ABE anchor installer that is equipped with the domestic P110-01 roadheader. The main additional advantages of the new roadheader are high reliability, hydrophilic temporary support, wet dust collection system, and remote control of all processes. According to [2], the EBZ-160JM heavy-type shearer meets the mining and geological conditions of the k_5 seam. Its main technical characteristics are as follows. The power of the electric motor of the executive body is 160 kW, the maximum dimensions of the entry face are height 4,5 m, width 5,6 m, rock strength in the face up to 80 MPa, specific pressure on the ground is 0,14 MPa, weight 60 tons, loading capacity - up to 2,4 m³/min. The proposed technological scheme of the roadheader driving looks like the following (Fig. 2).

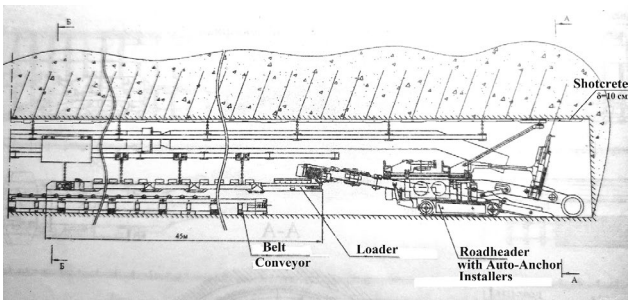

Fig. 2. The proposed technological scheme of the roadheader driving

The use of anchoring in the mine complies with the recommendations of the standard [3], the predicted relative convergence of rocks in the entries does not exceed 20%. Cross-sections of arched and rectangular entries with anchoring and shotcrete support used in the mine shown in Fig. 3, using the recommendations [3, 4]. A shotcrete mixture was being develop, which will include clay-containing rock crushed on site using a special crusher. Preliminary experiments have yielded positive results. The development and design of technologies is carried out by the mine's technological services.

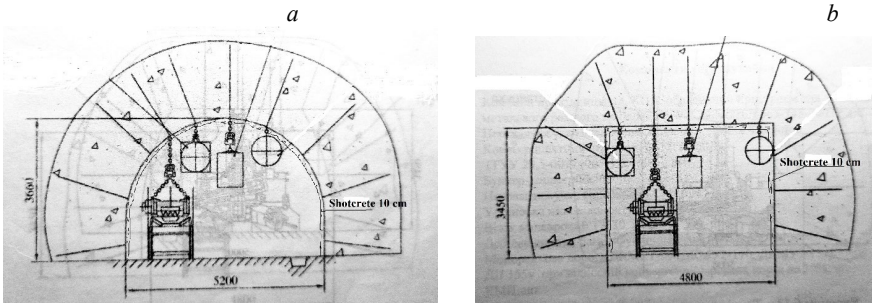

Fig. 3. Cross-sections of arched (*a*) and rectangular (*b*) entries with anchoring and shotcrete support

The coal industry has traditionally used and still uses two-tier design. Its essence lies in the fact those large projects for mine reserves planning and preparing carried out by specialized design organizations, and the so-called working projects or specialists of enterprises (mine administrations, mines) develop mining passports. The functioning of both levels regulated by a regulatory framework, with industry design standards at the center of it. Today, they dictate the "rules of the game" in the main areas of mining production, in particular, the driving and maintenance of mine workings [3, 4].

The current state and forecasts for the medium term indicate that the development of coal mining enterprises requires strengthening the system of detailed design of technological processes. This is because specialists of a particular enterprise often understand the peculiarities of the genesis of the deposit developed better than classical designers.

They see opportunities for the development of sections and the mine as a whole. An important advantage of production designers is also the availability of "feedback" in the form of quick receipt and analysis of specific results of their activities. Thus, the general situation actualizes the growth of industrial design activity and, accordingly, the formation of the regulatory framework of enterprises.

An enterprise standard (ES) is a regulatory document based on a specialized industry standard that reveals an algorithm for solving a technical problem in relation to the conditions of a particular mine management or mine.

In essence, the company standard is a part of the industry standard that was directly relate to this mine (mine management). The company standard reviewed by an organization that specializes in the relevant design area.

In general, major coal mining companies such as DTEK Energy, Metinvest Pokrovskvuhillia, and state coal mines Krasnolimanska and Kapitalna are systematically working on developing enterprise standards. The main attention and resources focused on developing rules for effective technological solutions implementing. This refers to the mine workings fastening and location, use of innovative materials, reuse of used special interchangeable profiles, installation (dismantling) of workings, ventilation of mining areas, etc.

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TECHNOLOGICAL FEASIBILITY OF USING FINE SCREENING IN PROCESSING FLOWSHEET

Relevance: The analysis of the basic ways to improve the quality of concentrates revealed that the basic increase in the mass iron fraction in iron ore concentrates is obtained by introducing auxiliary operations (fine screening, reverse cationic flotation), staged separation of concentrates, the use of advanced magnetic separators, etc. [1].

Flotation methods of concentrate benefication are widespread in the world. However, their high efficiency requires grinding to a particle size of the material to less than 45 microns [2,3].

Separation of production products and raw materials into grades or fractions can be preliminary, intermediate, or final, when the resulting fraction is a finished product [3].

Therefore, it can be assumed that the preparation of middling with staged the concentrates separation is the basic reserve for improving the mining inventory of benefication mining.

Research Methods: Laboratory and analytical research of beneficiation products, technological testing of the basic producing site on Benefication Plant and Flotation, calculation mass and water balance of beneficiation with determination of technological parameters of products.

Results: All research was carried out in conditions one of other Ukrainian Minning on products of current production.

To assess the possibility of using fine screening, technological testing of benefication process was carried out at the basic producing sites № 2, 4, flotation sites № 1, 2, as well as sampling for assessing the PSD analysis and chemical composition of benefication products.

Samples were classified on the testing screen analyzation "Analysette 3" with a collection material of each fraction and determination fraction yield. Quality control of sample separation into particle size fractions was performed visually using a binocular microscope.

One of the samples that was researched is a sample of the IV stage of magnetic hydroseparation concentrate, taken at the basic producing site № 2. The Fe_{tot}. content of the product is 61,71%, SiO_2 - 11,07%. The product is represented by the following size classes -32+0 μm - 66,6% (Fe_{tot}. 66.7, SiO_2 5,71), -40+32 μm - 12,4% (Fe_{tot}. 62,0, SiO_2 8,59), -50+40 μm - 8,6% (Fe_{tot}. 55,4, SiO_2 18,06), -63+50 μm - 4,6%, -71+63 μm - 3,0%, + 71 μm - 4,8%.

At fine screening according to class 50 μm Fe_{tot}. in the undersize product is 64,93%, SiO_2 7,33%, in the superlattice product - Fe_{tot}. 39,04%, SiO_2 - 37,47%.

The sample, which corresponds to the conditions of fine screening on the basic producing site № 4, is the III stage magnetic separation concentrate.

The Fe_{tot}. content of the product is 65,3%, SiO_2 7,39%. The product is represented by the following size classes -32+0 μm - 72,8% (Fe_{tot}. 69.1, SiO_2 2,88), -40+32 μm - 9.6% (Fe_{tot}. 66,3, SiO_2 7,7), -50+40 μm - 6,4% (Fe_{tot}. 62,2, SiO_2 8,53), -63+50 μm - 4,6%, -71+63 μm - 2,2%, + 71 μm - 4,4%. At fine screening according to class 50 μm Fe tot in the undersize product is 68,3%, SiO_2 3,81%.

At the basic producing sites of flotation № 1, 2, the final product is flotation concentrate. The Fe_{tot}. content of the product of basic producing site of flotation № 1 is 68,06%, SiO_2 - 5,66%, № 2 - 67,24%, SiO_2 - 4,6%.

Flotation concentrates are represented by the following size classes: site № 1: -32+0 μm - 79,4% (Fe_{tot}. 69,5, SiO_2 2,37), -40+32 μm - 11,7% (Fe_{tot}. 65.0%, SiO2-7,89%), -50+40 μm - 4,0% (Fe_{tot}. 57,5%, SiO_2 15,94%), -63+50 μm - 2,9%, +63 μm - 2,0%; the basic producing site of flotation №2: -32+0 μm - 72,7% (Fe_{tot}. 70,9, SiO_2 2,63), -40+32 μm - 12,9% (Fe_{tot}. 68,2, SiO_2 5,12), -50+40 μm - 8,7% (Fe_{tot}. 62,5, SiO_2 10,2), -63+50 μm - 1,8%, +63 μm - 3,9%.

That is, the use of a fine screening operation is expedient with in order to improve the quality of the concentrate.

At the basic producing site of flotation № 1, the quality of the concentrate is predicted at the level of 69,76%, SiO_2 at 3,66%, respectively at the basic producing site of flotation № 2 - 68,44% and 3,58% respectively.

Conclusions

1. Laboratory and analytical researches of samples of benefication products of the Ukrainian producer of iron ore concentrates have identified the most promising places for the implementation of fine screening in the technological process.

2. Optimal fine screening size is 45-50 micron.

3. Identified benefication products at different production sites that are possible and advisable for further screening.

3. At the basic producing site № 2, the implementation of fine screening will increase the quality of the concentrate of the primary processing flowsheet by 3,22%, and reduce the SiO_2 content to 3.74%.

4. At the basic producing site №4, the implementation of fine screening will allow to separate out the finished concentrate from the primary processing flowsheet before flotation with Fe_{tot}. content of 68.3% and a product yield of 88,80%.

5. At basic producing sites of flotation №. 1,2, it is possible to implementation fine screening of the final flotation concentrate, which will improving the quality of the concentrate at site No. 1 by 1,70%, reduce the SiO_2 content by 2,0%, at site № 2 raise the quality of the concentrate by 1,20% of total iron, reduce the SiO_2 content by 1,02%.

6. The next step is to conduct a semi-industrial test of fine screening, which will determine the real yield of undersize and oversize products, product quality, specific load, etc.

Key words: flotation, fine screening, stage separation, improving the quality

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OPTIMISATION OF DRUM MILL BALL LOADING IN THE FIRST STAGE OF ORE PREPARATION AT BENEFICIATION PLANTS

The cost of domestic magnetite concentrate is significantly higher compared to foreign analogues, because the costs of electricity, balls and liners, especially in the first stages of grinding, at Ukrainian concentrators are much higher. Improvement of the situation requires improvement of both controlled objects and automated control systems of the first stage of grinding. Therefore, the topic of this publication is topical.

The aim of the work is to optimize the ball loading of the drum mill of the first stage of ore preparation in ore beneficiation plants.

It has been experimentally established that ball loads of different sized balls provide higher throughput than single sized ball loads. Coarse and hard ores require larger balls, while fine and soft ores are better crushed with smaller balls. For each material size with a certain crushability, it is possible to select the ball feed size characteristic that gives the highest mill output. The ball feed size characteristic that provides the highest output is also selected by experience. It is clear that when optimizing grinding, it is first of all necessary to establish the best characteristic of ball loading size, which at the standard costs of energy, balls and lining provides the highest productivity of the technological unit for the ore of a given size and type.

The ball feed interacts with the coarse ore solid in the mill drum.

Recent studies of rocks have shown that five groups can be distinguished according to their grindability.

According to the classification introduced, the grindability of ores can vary from 0,94 to 0,4 - a little more than twice as much. A more specific idea of the characteristics of ores is given by the results of research within a single concentrator.

Ores are broken down under the influence of external forces. Important in this case is the change in loading and deformation rates, as well as the relationship between them.

Three material constants - static strength, static fracture toughness (crack resistance) and structural fracture time - are the determining parameters of fracture.

There is a wide variation in the grinding behavior of ores with respect to the grinding time, which can be attributed to the first stages of the process operation.

As each ore type has been found to grind according to its own patterns, either independently or in mixture with other ores, ore averaging technology does not provide optimal ore processing.

The situation is also complicated by the different inclusions of the useful component, which requires grinding of individual ores at different stages to a specific size.

Given the fact that the coarseness characteristics of the ball mill loading must be selected for each ore type to ensure the highest productivity, it is not practical to grind not only average ores, but also different types of ores in such mills.

If a different type of ore is fed to such a mill, it will not provide high productivity, which means overconsumption of electrical energy, balls and linings.

Therefore, in order to ensure high productivity of the ball mill, it is necessary to select a certain characteristic of the ball feed for a particular type of ore and not to change it during operation.

This allows us to give a schematic representation of the process of optimization of the ball loading of a drum mill (Fig. 1).

Here ore is the input parameter, and the output parameters are productivity Q_d for the finished product of size d, this product itself, unproductive overconsumption of useful power (electricity) ΔN and unproductive overconsumption of balls and lining ΔM_{KF}.

Ball and liner wear generates perturbing influences such as changes in the characterization of the X_K balls and the grinding media fill φ.

The controlling influences in this process are represented by the type of ore to be processed, the optimum X_{OK} ball characteristic that provides the highest throughput for a given ore type, and the balls that can be directed into the mill drum.

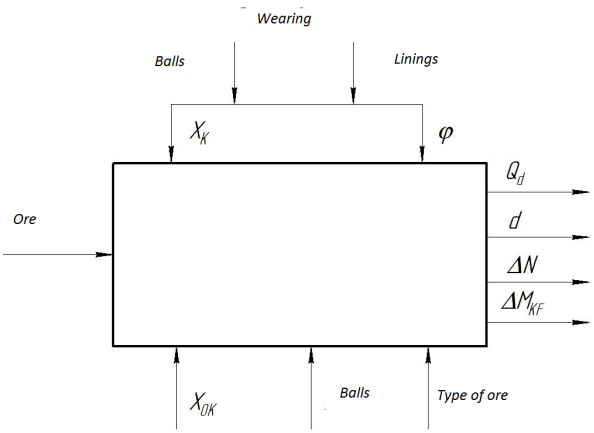

Fig. 2. Schematic representation of the process of optimizing the ball loading of a drum mill

The most time-consuming and important in the optimization of ore grinding processes is the selection of the ball mill performance criteria, i.e. the control objective. Since ore grinding is considered to be a preparatory process, technological criteria are used to control it.

Usually the optimality criterion expresses either the value of gain or the value of loss. Sometimes the optimality criterion is set quite easily in accordance with the essence of the problem; in many real-world problems the choice of the optimality criterion turns out to be a difficult problem. In cases of complex operations, it is common to deal with multi-criteria problems. Then the aggregate optimality criterion $J = \sum_{i=1}^{l} F_i(J_i)$, де $F_i(J_i)$ - functions of partial criteria; l - number of partial criteria. If the value of a win is proportional to J_i, then $J = \sum_{i=1}^{l} P_i J_i$.

The choice of weighting coefficients is problematic here. There are proposed approaches to solving such problems, but they are not without subjectivity. Sometimes relative weighting factors are introduced $\alpha_i = p_i \Big/ \sum_{i=1}^{l} p_i$ and achieve the maximum criterion $J = \sum_{i=1}^{l} \alpha_i J_i$, де $\sum_{i=1}^{l} \alpha_i = 1$.

Sometimes linear or quadratic functionals are used as optimality criteria. In any case, the functionals should be designed so that they more or less accurately reflect the actual losses or gains.

In this case, analytical expressions for functionals cannot be made more or less precisely.

Other approaches do not give encouraging results either.

Therefore, it is most appropriate to stick to the physical content of the problem and achieve the realization of the optimality criteria put forward.

In this process, three optimality criteria are physically distinguished $Q_d \rightarrow \max$, $\Delta N \rightarrow \min$ and $\Delta M_{KF} \rightarrow \min$.

If nothing changes in the subsystem, then, when controlling the ore loading, the output is crushed material to a size d with a capacity Q_d. Values $\Delta N=0$ and $\Delta M_{KF}=0$.

That is, the subsystem works without overconsumption of electrical energy, balls and lining. If the ore type is changed, the optimal characteristic of ball size [1] will not correspond to it and the subsystem will start overconsumption of electric energy, balls and lining.

Non-optimal ball loading, both in terms of ball volume and composition, leads to significant overruns [2].

Since it is impossible to change the ball size characteristic, it is not possible to prevent these overruns. It is only necessary to use ore of the specified type.

Waste of balls will lead to a change in the characteristic of ball loading and the degree of filling of the drum with grinding media, which will cause overconsumption of electrical energy, balls and lining.

It is possible to influence this condition by feeding additional balls, but it is necessary to establish the order of their formation and feeding. The wear of the mill lining is characterized by the same consequences [3].

Taking into account that this subsystem is autonomous, it is possible to control it by a separate automatic control device, but it is necessary to prove its structure and the order of formation of control actions.

So, it is possible to improve the ball mill of the first stage of ore preparation in concentrators as a controlled object by optimizing the ball loading.

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OPTIMIZATION OF FINAL CONTOURS OF PJSC ARCELOR-MITTAL KRYVYI RIH PITS AS PARAMETRIC ADAPTATION OF THE MINING COMPLEX TO DYNAMIC BUSINESS CONDITIONS

The high dynamics of external business conditions, which are characteristic of modern realities, causes mining enterprises to review the internal parameters of their production systems. Therefore, during the entire period of existence of any mining enterprise, there is a continuous process of

changes in both its production system and individual technological processes, due to the need to ensure its further development and adaptation to dynamic conditions, such as mining-geological, mining-technical, ecological, as well as social and economic factors.

Thus, PJSC "Arcelor-Mittal Kryvyi Rih" in order to respond to the complications of the external environment in 2022-2023 decided to carry out scientific research aimed at reviewing the parameters of open-pits in a final form. For this purpose, Scientific-research mining institute of the Kryvyi Rih National University took geological samples, studied their physical and mechanical properties, determined the stable parameters of the mine workings, analyzed preliminary design solutions and reviewed the final contours of open-pits №2-bis and №3.

The analysis of the provisions of the benches on the approved design contour of open-pits №2-bis and №3 showed that there are areas of faces where the width of the safety berms is greater than the minimum according to regulatory requirements. At the same time, the analysis of the physical and mechanical properties of the rocks of the massif of the side showed the potential to increase the angle of its slope. Considering this situation, the optimization of the approved design position of the sides of the open-pits was carried out by increasing the slope angle of the double bench to 70° and reducing the width of the safety berms to the minimum regulatory values. At the same time, the angle of inclination of groups of benches mostly remained within the limits that were determined in previous scientific papers on geomechanical calculations of stability.

Based on this, it was determined that the optimization of the final contours of the development of the Novokryvorizka deposit by open-pit №2-bis can be performed for parts of the northwestern, western, eastern and northern sides in the interval of horizons from -375 m to -120 m. At the same time, the -375 m horizon was optimized along the entire length of the eastern and northern sides. The displacement of the design position of the benches, groups of benches and faces of open-pit №2-bis was carried out by an amount that does not exceed the determined values when carrying out geomechanical calculations of stability in the range from 16 m to 20 m. As a result of the optimization of the approved design position, it was found additional volumes of ore mining and extraction of open-cast rocks. When calculating additional ore reserves, the average value of the density of magnetite quartzites was taken as 3,3 t/m^3. The additional volume of ore in the optimized working contours of pit № 2-bis is 5,2 million tons, overburden rocks - 0,2 million m^3, total mining rock mass- about 2,0 million m^3, and the additional overburden ratio is 0,04 m^3/t.

It was also determined that the optimization of the final contours of the development of the Valyavkin deposit by pit №3 can be carried out for the southern, eastern, northern, western and partially southwestern faces of the poen-pit in the range of horizons from -410 m to 0 m. Shifting benches positions, groups of benches and faces of open-pit №3 were carried out to a safe size in the range from 16 m to 18 m. In accordance with the optimization of the design position of open-pit

№3, additional volumes of ore and rock extraction were also determined. With an average density of magnetite quartzites of 3,5 t/m^3, the additional volume of ore is 22,1 million tons, overburden rocks - 2,1 million m^3, and total mining rock mass - about 9 million m^3. The additional overburden ratio is 0,1 m^3/t.

Thus, the investments of PJSC "ArcelorMittal Kryvyi Rih" in the research of safe parameters of prospective contours of open-pits № 2-bis and № 3 will ensure a decrease in the average overburden ratio and a corresponding improvement in the technical and economic indicators of the development of deposits while ensuring a high level of mining safety works.

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SOLUTIONS TO IMPROVE MINING EFFICIENCY FOR THE LONGWALL IN THICK, SLOPING SEAMS OF MAO KHE COAL MINE, VIETNAM

Improving mining efficiency in the longwall is extremely important in directing the operation and actual production of the mine. There are many factors affecting the efficiency of longwall exploitation, including the group of factors on geological conditions and technology. When choosing a mining solution to apply, it is necessary to analyze and evaluate those factors fully and clearly. However, due to the characteristics of mining, during the mining process, it is necessary to make flexible and timely adjustments to match the actual conditions of the longwall to ensure the best efficiency.

The longwall in Seam 6 at East Side of Mao Khe Coal Mine belongs to the thick, sloping seams. The fact shows that the output and labor productivity, as well as the top-coal caving rate have not met the requirements. Through assessment, analysis, combined with methods of comparison and synthesis of data collected at the mine, the author has selected a solution that can improve the efficiency of this longwall. Accordingly, the chosen solution is to preliminarily weaken the top-coal by drilling and blasting. After calculating the technical and economic indicators of the longwall, the output, productivity and recovery rate of top-coal have all been improved.

The research these results can serve as a basis for Mao Khe Coal Mine to apply in actual production in order to improve the efficiency of exploitation of the longwall in Seam 6 at East Side, contributing to improving the mining efficiency for the whole mine. This research result is also the basis to apply to other longwalls with similar conditions at Mao Khe Coal Mine.

For longwall mining technology with horizontal-inclined layers and stratified roadway, the actual annual mining output is about 0,45 million tons, accounting for ⅓ of the overall mining output of the entire Mao Khe mine [1,2]. However, because the geological conditions in the sloping seam areas of Mao Khe deposit are very complex.

Coal seams have many fluctuations in thickness and slope angle, coal in the seam changes from soft to hard, roof and floor of coal seam change complicatedly [3]. Therefore, some economic and technical indicators of mining technology are not as expected, such as: low coal recovery rate, which leads to high cost indicators, increasing mining costs and affecting the mining efficiency of Mao Khe Coal Mine [4,5].

Factors such as geological conditions, technical and technological factors all affect the efficiency of stratified roadway mining technology for thick and sloping seams [6-9]. In the world and in the country, there have been studies to increase mining efficiency for stratified roadway mining technology.

In the Quang Ninh coalfield, there have been specific directions such as research to increase the top-coal rate to reduce coal loss by preliminary weakening of the top-coal [10,11].

*** Proposing solutions to improve exploitation efficiency for the longwall in Seam 6 of Mao Khe Coal Mine**

When exploiting thick, sloping seams using stratified roadway mining technology, countries around the world and Vietnam have had a number of technical and technological solutions to increase efficiency in the longwall mining process. Specifically, the following two groups of solutions include:

+ *Solution 1: Group of solutions to preliminary weaken the top-coal*

The essence of this group of solutions is preliminarily weaken the top-coal of the mining stratifications, making it easy for the coal to collapse when caving. Depending on each specific condition, the group of solutions for preliminary weakening of the top-coal has three main solutions as follows:

- Preliminarily weaken the top-coal by pumping water

The essence of this solution is to drill long boreholes into the top-coal in front of the longwall face and then use pumps and high-pressure pipeline systems to pump water into the coal block from the above boreholes to breaking the pristine state and reducing the durability of the coal block to a convenient limit for top-coal caving.

- Preliminarily weaken the top-coal with a vibrator and a polarized wave generator

Essence of the solution: Use a vibrator installed in the tunnel dug in the top-coal in the pressure zone, 15÷20m from the mining mirror to create horizontal waves, causing distortion and destruction of the coal mass. The advantage of this solution is safety in mine conditions with explosive gas and dust; the high level of mechanization allows for increased output and labor productivity. The disadvantage of the solution is that the size of the coal block at the top-coal is uneven; In soft coal seam conditions, the effectiveness of the solution is low.

- Preliminarily weaken the top-coal by drilling and blasting

The solution of drilling and blasting to weaken the top-coal is the most commonly applied solution in underground mines around the world and in the country to improve top-coal caving rate when mining sloping seams.

Preliminary weakening of the top-coal by drilling and blasting can be done directly in the longwall face or from tunnels excavated in the top-coal in front of the longwall face. Five commonly applied solutions are as follows:

- Drilling and blasting weakens the top-coal at the longwall face;
- Drilling and blasting in large diameter boreholes;
- Simultaneous drilling and blasting into the roof and floor of the roadway;
- Drilling and blasting in long boreholes;
- Drilling and blasting in short boreholes.

+ ***Solution 2: Innovate support technology***

Reality shows that one of the factors that directly affects mining efficiency using stratified roadway mining technology is the support technology in the stratified roadway. In many longwalls exploited using stratified roadway mining technology in countries around the world such as China and Russia, mechanized shields have been used to improve support efficiency and increase top-coal caving rates, as well as improving safety during longwall mining [12].

In Vietnam, the stratified roadway mining technology with mechanized supports has been applied experimentally at Ha Long and Vang Danh Coal Mines. Although the application results have not been successful due to many different reasons, it is still the basis and has created good conditions for the domestic mining industry to access the technology of supporting by shield for applying short longwall face to exploit thick, sloping seams [13].

*** Selection a reasonable solution for the current conditions of longwall in Seam 6 of Mao Khe Coal Mine**

Two groups of solutions to improve mining efficiency for the longwall in Seam 6 have been mentioned above. In particular, solution group 2 applies support technology using the shields tested at Ha Long and Vang Danh Coal Mines.

Through evaluation and analysis, when applied in the Quang Ninh coalfield, there are still some disadvantages as follows [14].

(1) the shield has a large size and weight, not suitable for the limited space conditions of the stratified roadway, and is often misaligned;

(2) synchronization of equipment imported from abroad, so during the exploitation process, some parts of the shield were damaged and could not be replaced promptly, causing a loss of continuity and affecting the production process;

(3) the seam thickness changes strongly, fluctuating in large directions, the shields are linked together, thus limiting the ability to cut the longwall, leading to the longwall not changing direction in time, so the roof and floor must be cut, that affect the efficiency of longwall mining;

(4) Due to the characteristics of sloping seam mining, the upper mining stratification has ended, so the longwall has water flowing in from the terrain and the shield is sunk, and it is difficult to recover coal at the rear scraper conveyor;

(5) The process of moving the shields is affected by the impact of pressure on both sides of the roadway. At the same time, the shields are pushed into the inside of the roadway, leading to obstacles to the top-coal caving, or even impossible to cave.

The longwall in Seam 6 of the Mao Khe Coal Mine is already being exploited, the excavation of the stratified roadways has been completed, so to apply solution 2 to change the support technology, it is necessary to renovate the entire tunnel system, which requires cost and time, leading to production interruption for the mine.

Therefore, to improve mining efficiency, it is necessary to choose solution group 1, which is to preliminarily weaken the top-coal. In this group of solutions, there are solutions that can be applied. Through evaluation and based on actual conditions for a longwall in Seam 6, this study has selected a preliminary weakening solution.

This study has chosen the solution of preliminary weakening of the top-coal by drilling and blasting at the the stratified roadway in short boreholes. This solution is selected based on the mine's existing conditions in terms of current status, equipment and technology.

*** Conclusions**

- To improve mining efficiency in the mining technology diagram for longwall conditions of Seam 6. Based on experience in weakening the top-coal in domestic and foreign underground mines and to suit the geological and technical conditions of the mine, as well as the current state of technology and equipment available at Mao Khe Coal Mine, the author has researched, analyzed and selected the solution to preliminary weaken the top-coal by blasting in short boreholes from the stratified roaway to improve the top-coal caving rate and reduce coal loss in the stratified mining longwall.

- Based on the selected solution to improve the efficiency of the mining technology diagram for the longwall in Seam 6, in order to apply the research results to actual production, the author has conducted a design to apply the solution in specific conditions is a longwall in Seam 6. The results of calculating economic and technical indicators all show that it is more effective than the diagram that has not applied the solution of preliminary weakening of the top-coal.

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IMPROVING THE SAFETY OF KRYVBAS MINERS BY IMPROVING THE EQUIPMENT OF THE MINING RESCUE SERVICE

The mining industry of Ukraine is focused on the fulfillment of two main tasks: increasing the volume of mineral extraction while simultaneously increasing the level of safety of mining operations.

Every year, mineral extraction moves to deeper horizons. This, in turn, leads to an increase in mining pressure, the emergence of problems of ensuring the integrity of mining products and the deterioration of miners' working conditions. Therefore, the problem of providing mine rescuers with modern mobile equipment is urgent.

The analysis of the use of mining rescue equipment at the iron ore mines of Kryvbas showed what equipment is currently used in the mines and outlined problems related to its improvement.

Table 1

Mining rescue and auxiliary equipment, which is most often used, depending on the type of accident

Type of accident	Equipment used	
	mountain rescue	auxiliary
1. Fire	- manual fire extinguishers of various types; - fire hoses with barrels; - universal drill US-1; - water sprinklers VVR-1 and MVR-3; - foam generators; - powder fire extinguishing installations; - jumper package; - mining and carpentry tools; - stretcher	- electric locomotive; - trolleys
2. Collapse of mining rocks	- mining and carpentry tool; - various types of jacks; - hydraulic risers; - gas cutting apparatus; - stretcher; - rescue chair; - animating apparatus (GS-5)	- electric locomotive; - trolleys; - scraper winch; - drill hammers; - UGPS; - sheet pile hammer; - water resistant; - loading machines; - mine jack; - NKR-100M machines
3. Gas poisoning	- mining and carpentry tool; - jumper package; - GS-5; - stretcher	- electric locomotive; - trolleys
4. Flooding	- mining and carpentry tools; - stretcher	- electric locomotive; - pneumatic and other rock-loading machines; - trolleys
5. Falling into mine workings	- rescue chair; - rescue rope; - stretcher; - various types of winches; - device PPL-1	- baddya; - electric locomotive; - trolleys

Thus, it can be concluded that the elimination or minimization of manual labor, primarily in operations related to the delivery of equipment, equipment, as well as transportation of victims.

This concerns, first of all, the work of mining rescuers in lifting workings.

Because the increase in the time spent by mountain rescuers in an open working area, multiplied by a severe psycho-emotional state (loss of sense of time, decrease in control function, appearance of fear) leads to a high risk of injury.

As a result of the fruitful work of scientists of NDIBPG in the commonwealth with related specialized research organizations and design institutes, as well as with the participation of

specialists of mining enterprises and directly of VGRS, means of mechanization were developed to facilitate the work of mining rescuers.

In the direction of equipping mining rescue units with special vehicles suitable for operation in mine conditions, a whole complex of technical solutions has been developed, which includes:

- mobile (rail-mounted universal water-foam-powder fire extinguishing system UPP-600/750/900;
- universal mountain rescue train DSU;
- VGM-80 small-sized mountain rescue cart;
- VGU-500 universal mountain rescue cart;
- device for transportation (evacuation) of the injured (including severely injured).

injured) in mine trolleys PTP-ShV;

- reinforcement complex for quick construction of the temporary running channel in

lifting mining works "Hid-100 RVM";

- universal mining rescue winch "LGRU-100 RVM";
- small-sized monorail emergency and rescue lift "PGR-350".

According to the direction of mechanization during emergency and rescue operations in vertical shafts of mines, as well as during the performance by mine rescuers of technological works related to the inspection of the condition, for example, of ventilation shafts of mines that are not equipped with mechanized lifts, the following have been developed:

- mobile emergency and rescue lifting installation MASPU-2,5/1500;
- a special set of equipment for television inspection of mines ventilation shafts MKTS-0,5/1500.

Special vehicles developed for mining rescue units are suitable for operation in underground mining conditions.

New technical solutions make it possible to transport equipment for rescue work in horizontal and lifting mining operations, which saves time and the health of mine rescuers.

Developed and tested emergency and rescue technical means intended for mechanization during emergency and rescue operations in vertical shafts of mines, as well as during the performance by mining rescue workers of technological works related to the inspection of the condition, for example, of ventilation shafts of mines not equipped with mechanized lifts.

The acceptance commission confirmed the functionality of the developed equipment, compliance with its intended purpose, and recommended the developed equipment for mass implementation both at enterprises and in the units of the VGRS.

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EVALUATION OF THE POSSIBILITY OF APPLICATION IN PROCESSING FLOWSHEET OF HYDRAULIC SCREENING BY NEAR-MESH GRAIN

Relevance: Today's shortage of high-grade iron ore, increased use of low-quality, fine ores, and the need to process man-made deposits are forcing companies to update their technologies and look for ways to improve them and additional processing. These efforts are aimed at improving product competitiveness and reducing operating costs. Traditional separation and classification methods have low efficiency. The application of hydraulic screening by near-mesh grain in processing flow-sheets can be one of the operations to improve the efficiency of the processing and obtain a product of higher quality [1].

Research methods: Study of particle size distribution test and mineralogical composition of froth product and regularities of distribution of minerals on different fractions with the purpose of estimation of the possibility of use of hydraulic screen in processes of finishing of froth product flotation.

Results: Evaluation of the proposed research methods was carried out on the froth product one of other mining of Ukraine.

Particle size distribution test and mineralogical composition of the froth product revealed that it contains not only non-metallic minerals but also fine ore particles smaller than 20 μm. In addition, it is worth noting that in the froth product, the particles have larger sizes than in the initial concentrates, as the share of particles of +20 μm in size is 30%, while in the flotation feed this share is only 17%

In the mineralogical analysis of the froth product, it is found that these products contain different proportions of magnetite, quartz and silicates. Magnetite is the main ore mineral containing iron. Minerals such as hematite, silicates, ore carbonate and iron sulfides come next in terms of quantitative content. Non-ore components are quartz, dolomite, calcite and apatite. Impurities that negatively affect the quality of the final product are sulphur and phosphorus, which are carried by iron sulphides.

It is in particles of -20 μm in size that the maximum mass fraction of total iron is concentrated - 64.6%. The material of -20÷+0 μm fraction by mineral composition is a mixture of revealed magnetite particles (64%) with the admixture of revealed quartz and silicate fragments (26%). The content of aggregates with quartz is insignificant. There are also aggregates with cummingtonite, and occasionally with garnet.

The +20 μm class contains point inclusions of ore mineral. Fully revealed quartz is represented in the -10 μm class.

The given results for the size classes of the froth product suggest the possibility of using a hydraulic screen for the separation of the froth product. The optimum size of the screen opening is 20 μm. The separation of the froth product into fractions of +20 μm and -20 μm will allow the separation in undersize product mono-mineral particles of magnetite with the insignificant admixture of ore-not ore aggregates and revealed particles of quartz, silicates [2, 3, 4, 5].

It should also be noted that the froth product is a very flocculated material, and measures to reduce this phenomenon should be provided for more efficient separation on the hydraulic screen.

Conclusions

As a result of the analysis of granulometric and mineralogical composition, it is established that the material of -20÷+0 μm fraction is a mixture of released magnetite particles (64%) with admixture of released fragments of quartz and silicates (26%).

The granulometric composition of the froth product allows us to determine the possibility of application in the processing flowsheets of hydraulic screening by near-mesh grain of 20 μm. Further, it is necessary to provide additional operations on processing of undersize and oversize products of the screen, and also for the creation of optimum conditions of segregation to develop measures on deflocculation.

Key words: near-mesh grain, froth product, hydraulic screening.

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RESEARHC ON BIOCONVERSION AND IMPROVEMENT OF TECHNOLOGICAL OPPORTUNITIES FOR BIOGAS FURNISHING

The bioconversion of organic waste is one of the most advanced, cost-effective and environmentally acceptable solutions for preventing environmental pollution. It makes it possible to rationally use organic substances and save the energy accumulated in them.

For the further sustainable development of Ukraine, a system of building environmentally friendly energy and resource-saving bioconversion processes for organic waste is needed to prevent environmental pollution, produce high-quality fertilisers that increase crop yields and at the same time restore the humus layer, and a gaseous energy carrier - biogas. The efficiency and reliability of the bioconversion process largely depends on the organisation of power supply and thermal stabilisation of the bioreactor. This can be achieved in different ways. The most efficient way is to use a hot water boiler that burns gaseous fuel. The operation of domestic and imported boilers is accompanied by environmental pollution with harmful emissions. In addition, Western European countries have developed standards for NO emissions$_x$ from biogas combustion, but there is no such data for Ukraine yet.

Therefore, due to the need to create environmentally friendly balanced bioconversion systems, methods and means should be developed to reduce harmful emissions from energy supply subsystems to bring them closer to the standards in force in Western Europe. Currently, there are no standards for permissible emissions from biogas boilers. To develop such a regulatory framework, it is necessary to use international experience and own fundamental research.

Currently, the main sources of biogas production are individual and farm households, food and processing enterprises, and livestock farms [1]. An exampleis a biogas plant installed at the livestock production facility of Zaporizhstal (Fig. 1,2). This plant processes waste from a livestock complex that rears10,000 pigs per year.

Fig.1,2. Zaporizhstal's quality control department

To cover the heating and hot water supply needs of the complex, a boiler house with two hot water boilers from "Danfoss (Denmark) VBN-630 with a capacity of 730 kW each with Weishaupt C7-1-D burners. These boilers can run on biogas or natural gas, which is used as a backup fuel in the boiler house.

Results of experimental and numerical

Research

According to the analysis of available information, there is no data onstudies of biogas boilers in Ukraine. The exception is the work of the author [4] with the results of solving the specific problem of developing underfloor burners for boilers of the DKVR type. Thus, the scientific and technical basis for the development and implementation of biogas boilers and heaters has not been prepared.

To further study the environmental and energy performance of biogas-fired boilers, experimental studies will be conducted on biogas and, for comparison purposes, some experiments will be conducted on natural gas. All experimental studies will be carried out at a test bed installed at the auxiliary facilities of the metallurgical plant "Zaporizhstal. According to laboratory tests, the elemental composition of the fuelswas revealed, as shown in Table 3.

Type of fuel	*Content of the component in the fuel, %.*											Estimated calorific value, MJ/m^3
	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	N_2	CO_2	O_2	H_2	CO	H_2S	
Biogas	66,4	–	–	–	–	0,3	28,3	0,8	–	3,2	1,0	24,0
Natural gas	98,0	0,4	0,3	–	–	0,5	0,5	0,3	–	–	–	35,6

To compare the results obtained using the experimental bench and the calculated numerical data, experimental studies on an industrial boiler unit are also planned "Weishaupt VBN-630 with a capacity of 730 kW (Fig. 3), with a burner "Weishaupt" C7-1-D, the boiler is equipped with automation from Danfoss (Denmark).

Fig. 3. Weishaupt VBN-630 boiler unit

This hot water boiler has a two-way horizontal cylindrical design. The water volume contains a cylindrical furnace with a horizontal axis ∅ 700 mm, a rotary chamber and a horizontal heat-tube bundle made of pipes ∅48/41 mm. According to the calculations, the radiating surface of the furnace and the rotary chamber is 5,683 m^2, the total surface area of the bundle is 15,52 m^2.

In order to increase the energy efficiency of the boiler and intensify heat transfer in the heat-tube bundle by means of additional radiation, we inserted platesalong the entire length of the tube, 29 mm wide and 2,5 mm thick, into each tube (Fig. 4).

Fig. 4. Weishaupt VBN-630 boiler unit (with plates)

Due to the high temperature of the gases, the plates heat up and radiate heat to the outer walls of the pipe. As is well known, the radiation from the plate tothe pipe wall, if there is a gas flow between them, is much more intense than the radiation from the gas flow to the pipe wall [5].

Conclusions

An analysis of the current energy and environmental situation has shownthat biogas technologies are a promising unconventional energy source for Ukraine, which, in addition to a certain energy effect, can reduce the environmental burden through the efficient processing of organic waste. The installation of steel plates in the heat-tube elements to improve the boiler's efficiency helped reduce the temperature of the exhaust gases and excessair in them. In order to create a regulatory framework for the development and certification of biogas boilers, it is necessary to conduct a set of environmental and thermal studies of their operation, as well as to develop methodological foundations for the design of domestic and industrial boilers.

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ANALYSIS OF THE EFFICIENCY OF USING METHANOL TO PREVENT HYDRATE FORMATION IN GAS GATHERING AND PROCESSING SYSTEMS

In the last two decades, there has been noticeable progress in increasing the efficiency of the use of the most widely used in the gas industry inhibitor of hydrate formation - methanol. First of all, this is due to the development and implementation of new technologies based on the property of this volatile reagent to undergo phase transitions during low-temperature gas processing.

Computer simulations are used by engineers in the fields of design, development and gas hydrate risk management for oil and gas streams, both for the capital expenditure (CAPEX) and operational expenditure (OPEX) stages.

Accumulating of researches on gas hydrate formation will be important to the oil and gas industry, especially given the relatively recent increase in the development of deepwater fields where gas is collected and transported under extreme conditions that are more vulnerable to gas hydrate plug formation [6, 7].

Thermodynamics provides a powerful tool for predicting the temperature and pressure at which hydrate formation occurs for a gas of known composition. However, even when gas hydrates can form thermodynamically, they may never form.

The kinetics of hydrate formation are complex and poorly researched, partly because the process of crystal growth depends on many variables. Due to this uncertainty, the operating parameters for the technological process must be outside the hydrate formation area [1, 3] .

Modern pumping equipment can perform dosing of inhibitors without their leakage into the environment, and also provides the possibility of automatic and accurate regulation of the flow rate of the inhibitor depending on its need in the technological process.

One of the promising research fields is the development of technologies that allow automatically changing the dosage of the hydrate formation inhibitor depending on the composition of the gas and the current operating parameters of the technological process.

It was also recently discovered that methanol in ultra-low concentrations (from 1 to 30 wt %) creates a double effect, under certain thermobaric conditions it can work not only as an inhibitor of hydrate formation, but also as an activator of gas hydrate formation [2,4], however, this phenomenon still needs additional researches and studies.

Technologies for injecting the inhibitor into pipelines and equipment during low-temperature gas treatment are constantly being improved, which allows for more effective interaction of reagents with the working environment and, accordingly, to avoid excessive consumption of the inhibitor [5,8,9].

The analysis of the distribution of methanol in the input and output streams of technological installations for low-temperature gas preparation makes it possible to determine the possibility of collection, regeneration and reuse of the inhibitor of methanol hydrate formation, which leads to a significant saving of the reagent [10].

The improvement of inhibitor regeneration technologies contributes to the reduction of capital and operational costs for conducting such a process.

The industrial production of methanol is an energy-consuming process, therefore the rational use of such an inhibitor is important.

A comprehensive approach to conducting a technological process for low-temperature preparation of natural gas and, based on this, the development of a more effective technology for the use of methanol in the gas industry is extremely relevant.

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DRILLING AND ENVIRONMENTAL ASPECTS WHEN CONSTRUCTING WATER WELLS

Today, there are many questions about meeting the needs of industry with various minerals. Water is such a useful resource. We can also talk about the need to improve the quality of water for domestic needs. The main solution to these problems should be the creation of alternative sources. The most acceptable of them will be boreholes [1].

Well drilling processes are quite complex. Very often they are accompanied by the occurrence of various complications. The problems of well construction include the difficulty of drilling in hard rocks and the possibility of environmental pollution of productive horizons. This is just a small list of difficult well drilling situations [2].

Borehole water production is quite capital-intensive. It can be reduced by constructing wells with high productivity rates. Such wells should make fullest use of the potential of the productive aquifer.

A significant reserve for reducing production costs is minimizing operating costs. Such costs are determined by the need to purify water with special filters. For their reliable operation, they must most closely match the rocks of the water collectors. Filters must be periodically subjected to maintenance related to their cleaning in well conditions. A fairly high level of financial costs also falls on pumping from the well. To do this, they must be carried out with energy-efficient deep or surface pumps [3].

Simplifying the well design can also help reduce the overall cost of water production. However, with this approach, it is important to prevent the possibility of a negative violation of water quality

indicators. It is also necessary to constantly take into account the avoidance of negative impacts of any improvements on the environment. This is a fairly accurate indicator of the applicability of various solutions [1].

The construction of water wells is carried out in various ways [4]. The most important of them can be called rotary (using rotary drilling units), cable-churn drilling; auger drilling. However, most often they replace the rotational method with flushing wells with industrial water or clay solution (mud). The cable-churn drilling method is useful when there is very limited information regarding the geological and hydrogeological features of the well. This method is necessary to open unconfined aquifers. It is rational to use it even if it is impossible to ensure a stable water supply for flushing wells during drilling.

An important and mandatory component of the design of water well is the water intake part. Such an element is located in the productive (aquifer) horizon. As a rule, the water intake part of the well is equipped with a filter of appropriate design. There may be no filter in the water intake part of the well. This case corresponds to the location of the well in solid crystalline rocks [5].

It is advisable to drill water wells in crystalline rocks using a rotary method. The mechanical drilling speed will be significantly lower than when drilling in sedimentary rocks. In this case, the use of the percussive-rotary method can be considered effective. This method requires the use of special hydraulic machines that generate impacts of a certain frequency and strength [6]. These machines are called hydraulic hammers (fig. 1).

Fig. 1. Hydraulic hammer

The authors of the article proposed a rational version of the hydraulic hammer design for use. This machine is distinguished from other known ones by the presence of new structural elements. At the same time, new elements do not lead to significant complication of the design. They only ensure the appearance of correct technological interaction between the individual elements of the hydraulic hammer. Thanks to the modernization of the hydraulic hammer, the ability to control energy indicators and parameters of rotary impact drilling modes is achieved [7].

The design of the hydraulic hammer actuator assembly allows the generation of a shock pulse of various amplitudes.

The type of hydraulic machines under consideration allows their use in various cases of drilling wells. The performance indicators of improved hydraulic hammers suggest that they improve the perfection of the use of hydraulic and mechanical power of drilling pumps, machines and other devices.

Due to their use, the mechanical and cruising speed of well drilling increases.

A hydraulic hammer for drilling consists of the following main parts: a slot sleeve, which is connected by a movable joint to a hollow body using vertical running slots. The body contains a hammer valve (made of a stepped design), consisting of a distribution circulation rod with a central and side channels, and it is also equipped with a system of sealing rings that ensure smooth movement of the hammer valve [8].

The technical result for the proposed hydraulic hammer is as follows.

The new design of the working bodies and the flexibility of their interaction mode together ensure the hydraulic perfection of the circulation processes in the hydraulic hammer.

For such a machine, complete implementation of the hydraulic well cleaning program is achieved. Increasing the mechanical drilling speed helps to reduce the time the wellbore remains open.

You can track it like this. Quickly obtaining a wellbore in the thickness of the rocks allows you to proceed to its fastening in the shortest possible time. In other words, the possibility of clogging productive horizons with components of flushing fluids (mud) and parallel disruption of the natural state of the geological environment is prevented.

The negative impact on the geological environment during well drilling can be prevented by successively covering the drilled intervals with casing strings and cementing them.

The cementing operation avoids the movement of fluids between different horizons and their active mixing. The important thing here is the use of high-quality cements and appropriate well preparation.

For cement mortars, the main requirement will be to create a strong and impervious cement stone. Such a stone should eliminate or reduce the likelihood of corrosion for metal casing pipes.

An analysis of the work performed by drilling enterprises indicates that the most vulnerable component of the environment during the construction of wells is groundwater - this is a consequence of their prevalence, dynamism and resource value.

This means it is necessary to prevent harmful substances (representatives of the formulation of flushing fluid (mud) and cement mortars) from entering aquifers.

To preserve water quality, as well as prevent contamination of groundwater deposits, sanitary protection zones are established.

In such zones, special measures are introduced to eliminate the possibility of contamination of aquifers.

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PRECONDITIONS FOR THE USE OF COMPOSITE MATERIALS IN MINE SUPPORT ELEMENTS

Ukraine's coal industry stands at a crossroads, facing the global impact of decarbonization trends [1, 2] and the closure of mines, while also dealing with the challenges of post-war reconstruction and the preservation of energy independence [3].

At present, one of the primary tasks in improving underground coal mining is to develop effective means and methods of ensuring the stability of excavations. Ensuring the stability of mine workings in coal mines remains one of the most critical issues in mining production, as the efficiency and safety of mining operations depend on their operational condition.

The need to create new means of supporting mine workings with significantly improved stability parameters and working characteristics is driven by the substantial demands placed on support systems and the complexity of mining and geological conditions.

Over the last decade, the depth of coal seam exploitation in Ukrainian mines has significantly increased, leading to the destruction and deformation of support systems in 37-53% of the studied mine workings, with up to 12-25% fully reinforced. At greater depths, the cross-sectional area of mine workings, the spacing of supports, and the mass of support systems have increased. The cross-sectional area of workings has increased from 11,2 m² to 13,8-17,7 m², and sometimes up to 22-25 m² in deep horizons. This is primarily due to economic requirements for intensifying coal production (increased load on the ventilation drift) and technological needs to maintain proper ventilation, gas control, and temperature conditions during mining operations. Collectively, this has resulted in a significant increase in the consumption of steel products for mine support.

Common types of deformation in arch support systems include the deflection of the roof (in its central part) where concentrated loads and bending moments occur. This indicates a significant mismatch between arch support systems and mining-geological conditions, operation, and the intensity of rock pressure. The parameters of the applied supports do not account for the specific features of geodynamic impact during excavation, changes in the stress-strain state of the "sup-port-massif" system at different stages of operation, preventing the optimal use of the rock mass's load-bearing capacity and increasing the costs of mining and supporting mine workings.

For deep-level mine horizons (H>1000 m), research [4,5] has focused on improving mine working support systems, indicating that existing drawbacks of traditional methods can be mitigated or even eliminated by using modern technologies and materials.

An alternative solution to the current challenge of supporting mine workings and enhancing their stability in coal mines involves a shift from metallic materials to composite materials. Stud-ies [6,7] have explored the possibility of using composite materials, specifically carbon fiber-reinforced plastics (CFRPs), for mine support systems. These materials possess high heat re-sistance and long-term resistance to mechanical stresses, which are essential qualities for mine workings.

Analyzing the physical and mechanical properties of support materials, it becomes evident that composite materials offer clear advantages with only minor drawbacks. In research [8], the use of CFRPs as a support material was justified due to their high tensile strength at extremely high elastic modulus and low density and creep. The tensile strength of this composite material reaches 1400 MPa, equivalent to that of steel used in support systems, while the density of CFRP is 1500 kg/m^3, in contrast to the 7500 kg/m^3 density of metal.

As a result of the analysis of the degree of study in the development of fasteners from composite materials, it can be noted that such studies were not purposefully conducted. Most often, similar scientific studies are found in the framework of works related to the development of new types and methods of fastening mining products, namely, with resource-saving technologies [9, 10]. Similar works were carried out at different times using current scientific approaches.

In connection with the plasticity of composite materials and their properties, there is the possibility of printing carbon fiber fasteners on a 3D printer and further research of such materials on hydraulic presses [11].

From the above, it can be concluded that this innovative material will be five times lighter than steel. For example, CFRP-reinforced materials may be denser than aluminum, but they can have double the modulus and up to seven times the strength. This type of composite material boasts high heat resistance and long-term resistance to mechanical stresses, making CFRPs more desira-ble for industrial use compared to other composite materials.

However, the current limiting factor is the cost of carbon fiber-reinforced materials, which is expected to decrease as demand increases.

The use of CFRPs in mine support elements will result in lighter constructions, reducing labor intensity during installation and dismantling, as well as improving miners' safety.

In summary, it can be concluded that CFRPs, as innovative materials, can be used in the construction of mine support elements in coal mines. CFRPs have properties that surpass those of aluminum and metal. Carbon composites offer high heat resistance and long-term resistance to mechanical stresses, making them highly sought after in industrial production.

As the cost of carbon fiber-reinforced materials decreases with increased demand, the use of CFRPs in mine support elements will in-crease work efficiency, reduce labor intensity, and enhance miners' safety.

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CALCULATION OF DIFFERENT HYDROJET WATER-POLYMER PERFORATION MODELS FOR OIL AND GAS WELLS

A thorough investigation into the response of aqueous polyethylene oxide (PEO) solutions to hydrodynamic impact revealed how deformation effects manifest in the flow of PEO solutions through a jet-forming nozzle in a hydroperforator. The intricate scientific method was vital for accomplishing the tasks successfully, both scientifically and technically. This is because the formation of supramolecular structures in aqueous PEO solutions was examined and differentiated under the impact of a hydrodynamic field, while taking into account the influence of all stages of the mutual interaction between the solution and the hydrodynamic field's configuration. At the same time, original methodological techniques were used to study the behaviour of PEO macromolecules in the hydroperforator nozzle inlet area. It was possible to create a new structural concept based on the significant deformation effect of the hydrodynamic field on macromolecular tangles of PEO. This leads to the instant development of rubber-like properties, with the formation of associates having a high degree of elasticity, similar to rubber, regardless of their nature. [1, 2] The method for developing the scientific and theoretical foundations of the hydroperforation process using a water-polymer jet is based on the rubber-like properties of aqueous PEO solutions. These properties can arise under specific flow conditions through the jet-forming nozzle.

The calculation of PEO aqueous solution flow modes through the hydraulic perforator nozzle relies on an established criterion that indicates the start of the "lump-expanded chain" transition and the formation of dynamic structures in the polymer solution. For this reason, it is necessary to compute the technological indicators while ensuring that the inequality is satisfied

$$\dot{\varepsilon} \cdot \theta_c \geq De_{er} . \quad (1)$$

Equation (1) can be interpreted as the Deborah number as it represents the flow time scale, which is the inverse of the longitudinal velocity gradient [3]. Thus, to calculate this, the relaxation time θ_c of the PEO solution and longitudinal velocity $\dot{\varepsilon}$ gradient at the inlet section of the hydroperforator nozzle need to be determined.

The relaxation time θ_c can be found experimentally by referring to the results presented in [1]. The relaxation time can be calculated using an analytical expression that relates θ_c the concentration (C_{PEO}), temperature, and molecular properties of PEO

$$\theta_c = \begin{cases} \theta_0 e^k & when\ k < 1 \\ \theta_0 \dfrac{e^{k^{2/3}}}{k^{1/3}} & when\ k > 1 \end{cases}, \qquad (2)$$

where $k=[\eta]_0 \cdot C_{PEO}$, $[\eta]_0$ is the intrinsic viscosity.

The experimental points for the molecular weights of $6 \cdot 10^6$, $4 \cdot 10^6$ and $2 \cdot 10^6$ correspond to the curve calculated using expression (2). The expression takes into account the effect of temperature through the temperature dependence of θ_c and k.

To determine the longitudinal velocity gradient $\dot{\varepsilon}$, solve the equation of motion of a Newtonian fluid in a confusor that refers to the nozzle inlet (see Fig. 1).

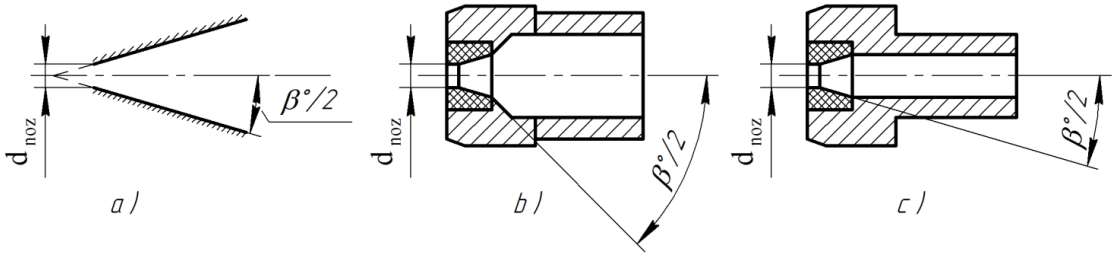

Fig. 1. Cross-section of the jet-forming inlet section:
a - Nozzle Diagram; *b* - Nozzle of a Prototype Hydraulic Perforator; *c* - Nozzle of an Industrial Hydraulic Perforator

A natural limitation of using the velocity gradient relation obtained from solving the problem of a Newtonian fluid flow in a confusor for calculating $\dot{\varepsilon}$ during the flow of an aqueous PEO solution is the flow rates and inlet angles required to manifest the supercritical mode of flow from the jet-forming plunger perforator. Therefore, the critical number De_{cr} will differ experimentally from the theoretically obtained value by Peterlin, where De_{cr}=0,5 [1-4]. Thus, the critical (hypothetical) Deborah number is the point at which the water-polymer jet surpasses the destructive power of the water jet.

From hydromechanics, it is known [4] how to solve the equation of motion for a Newtonian fluid in a confusor. In the event that the longitudinal velocity gradient in the nozzle inlet is not too large, the expression $\beta^o < \frac{\pi}{2}$ can be simply conveyed as: $\dot{\varepsilon} \approx 2Qtg\frac{\beta^\circ}{2} / A \cdot d_{noz}$, with Q representing the outflow rate of the polymer solution, A - as the nozzle's permeability coefficient, d_{noz} - as the diameter of the nozzle, and β - as the angle shown in Fig. 1.

Taking into account the above, the condition for the formation of dynamic supramolecular structures in aqueous solutions of PEO when they flow out of the nozzle, which should be fulfilled when calculating the modes of water jet water polymer perforation of oil and gas wells, as well as when designing the configuration (shape) of the jet-forming nozzle of the hydroperforator, is as follows $[\eta]_0 \cdot C_{PEO} \le 1$

$$\frac{\theta_{\exp}\left\{\left([\eta]_0 \cdot C_{PEO}\right)\cdot 2Qtg(\beta^\circ/2)\right\}}{d_{noz}^3} \geq D_{cr}, \quad \text{when } \beta^\circ < \frac{\pi}{2} \tag{3}$$

As per the experimental data, the critical Deborah number was adopted as 1,0, replacing the determination $A \cdot d_{noz}$ made experimentally d_{noz}^3. From equation (3), it can be concluded that an exceptionally high destructive potential of a water-polymer jet at a flow rate $Q \geq Q_{cr}$ intensifies with augmenting the nozzle entrance angle, jet velocity, concentration and molecular weight of the PEO, as well as with decreasing the diameter of the nozzle opening.

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IN-RESERVOIR CATALYSIS AS A METHOD TO IMPROVE THE DEVELOPMENT OF HARD-TO-EXTRACT HYDROCARBON RESERVES

Oil and gas resources are expected to continue to lead the future energy mix. The International Energy Agency (IEA) reported that in 2019, fossil fuels accounted for more than 80% of the world's total energy supply, with oil, natural gas and coal accounting for 31,27% and 23,0% respectively [1]. With the increasing depletion of conventional reservoir resources, researchers are gradually focusing on the development of large deposits of heavy oil [2].

Heavy oil is an unconventional oil resource with rich reserves, accounting for 70% of the world's oil reserves [3], so it has attracted great attention from countries around the world. Heavy oil reserves are approximately 750 billion tones, of which 160 tones are considered recoverable. More than 70% of hydrocarbon resources, i.e., an estimated 991,18 billion tones of heavy oil, are stored in 69 heavy oil basins worldwide [3].

Also, hard-to-extract reserves include gas condensate that has fallen out of the reservoir, the so-called retrograde condensate. Retrograde condensation of the hydrocarbon mixture negatively af-

fects almost all technological processes of condensate production. Reservoir losses of gas condensate during the development of gas condensate fields in the depletion mode average 60-78% [6].

The main methods of developing high-viscosity oil fields are as follows [4]:

- thermal: water vapour stimulation, reservoir combustion, electromagnetic heating;
- miscible and immiscible displacement by gaseous agents: (hydrocarbon gases, CO_2, nitrogen, flue gases);
- chemical: Surfactants, polymers, diluents, microbiological preparations;
- physical: exposure to physical fields.

Each method has positive and negative aspects. The disadvantages include high cost and environmental problems [5].

For the rational development of hydrocarbon reserves, efficient and environmentally friendly oil recovery enhancement technologies are needed. Large-scale implementation of new methods will help stabilise and even increase oil production.

The rational development of hydrocarbon reserves requires efficient and environmentally friendly oil recovery technologies. Large-scale implementation of new methods will help stabilise and even increase oil production.

At this stage, heavy oil production technology is not yet mature, and the cost of production is relatively high. Therefore, the question of how to extract heavy oil resources has become a pressing issue in the world.

Due to the characteristics of heavy oil itself, namely high viscosity and low fluidity, the thermal recovery method is widely used around the world. Cyclic steam stimulation, hot water and steam injection, steam-assisted gravity drainage and in situ combustion are the most developed thermal methods. Currently, heavy oil recovered by steam injection accounts for 80% of thermal oil recovery, which is considered the most commonly used method of oil recovery.

At the same time, thermal methods, by exploiting the temperature sensitivity of heavy oil viscosity, are effective for its recovery from shallow and thick formations. In addition, thermal methods are limited by the appropriate equipment and complex operation process. Given the Paris Agreement on Climate Change, which requires significant reductions in greenhouse gas emissions, the oil industry needs advanced technologies with minimal environmental impact.

Consequently, several challenges, including high energy costs, greenhouse gas emissions, inefficient heat transfer, water requirements and low energy efficiency, have necessitated the search for more efficient alternatives.

Therefore, methods of realising efficient development of heavy oil resources have become a major research focus. Thus, an effective increase in the oil recovery factor is an urgent task for the oil industry.

When large volumes of steam are injected, super-heavy oil becomes mobile. Steam-assisted gravity drainage (SAGD) has demonstrated the effectiveness of the extraction process for extra heavy oil. However, large volumes of steam are required to heat the viscous oil, resulting in high consumption of natural gas and water, which affects its economic benefits. However, this favourable technology is limited by low oil prices, carbon dioxide emission reduction requirements, and unproductive heat losses.

Surfactants and multi-component chemical systems are increasingly being used to improve the efficiency of SAGD. At the same time, the addition of chemicals, especially surfactants, is not economically viable in most cases. Thus, the industrial use of chemical agents for thermal oil recovery is limited.

Steam and solvent assisted gravity drainage (ES-SAGD) technology can produce lower cumulative steam-to-oil ratios than SAGD. This means that a process that uses both steam and solvent can be designed to significantly reduce the amount of steam injected. However, the problem is the low solvent recovery in the process cycle.

The combined injection of steam and carbon dioxide and chemicals is an effective approach to enhance heavy oil recovery.

However, the implementation of this technology is limited by the current lack of research on the synergistic effect of CO_2 and chemicals on improved heat transfer.

Today, improving the characteristics of heavy oils directly in the reservoir through catalytic aquathermolysis is an interesting alternative to viscosity reduction. Catalytic aquathermolysis shows significant application potential for the extraction of ultra-heavy oil and has therefore attracted much attention in recent years.

However, the known catalysts have demonstrated a number of drawbacks during pilot applications. For example, for water-soluble catalysts, poor interaction with oils in the formation can reduce their catalytic effect.

In addition, for metal oxides, the complexity and high cost of the injection technique, as well as the possibility of pore clogging during long-term filtration, can increase the cost and risks of their use.

At the same time, oil-soluble catalysts can avoid the above problems due to their advantages, including good interaction (contact) with crude oil, which leads to a high catalytic effect, and easy injection into the oil reservoir by pre-mixing them with an organic solvent.

Thus, the use of hydrocarbon production stimulation based on catalytic aquathermolysis for fields with hard-to-extract reserves is extremely relevant for increasing condensate and oil recovery.

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DEVELOPMENT OF TECHNICAL PROPOSALS FOR THE DESIGN OF THE SITE FOR INDUSTRIAL DEVELOPMENT OF THE ZEOLITE-SMECTITE TUFF DEPOSIT

When designing a tuff deposit's WHP (well hydraulic production) at the stage of feasibility study or technical project, it is necessary to determine: mining productivity as a function of reserves and consumer needs; method of discovery, technological scheme and system of field development; parameters of development systems and parameters of WHP technology [1-3].

The design of a mining enterprise is a system of calculation methods and specific recommendations. The main task of designing the development of a tuff deposit is the choice of a rational system of development, in which reserves will be extracted with the least losses and costs. At the same time, the rational use of mineral resources, measures to protect nature and the environment should be taken into account [4-6].

The design of the section of WHP of zeolite-smectite tuffs of the Rafalivskoye deposit is a complex task, in the solution of which the ore layer, mining chamber, well and surface equipment are considered as a single unit. An important point is the consideration of mining-geological and technological factors, and a specific feature is the possibility of adjusting the parameters of the technology during the operation of the deposit without changing the basic decisions.

The choice of a method of managing rock pressure during design is a separate task, the solution of which determines the parameters of the development system and its indicators.

The formation of underground chambers during WHP is one of the central processes of the technology and fully determines the level of technological losses of the mineral. In connection with this development project, issues of management and control of the shape and size of cameras are being resolved.

The design itself is a closely interwoven multifactorial connection of all sections: geological, technological, mining, economic.

For the design of water supply systems, a hydrogeological characterization of the deposit is necessary with the selection and indication of the parameters of aquifers, filtration properties of water-saturated rocks. Groundwater quality, direction of movement, chemical composition and physical properties. In addition, data on the distribution and characteristics of waterproofing in the sections of the roof and sole rocks are needed. These data are presented in the form of maps of the capacities of aquifers, stratoisogypsum roofs, mineral water conduits, and aquifer mountains-umbrellas.

The physico-mechanical properties of the rocks of the deposit affect the main processes (hydrodegradation, stability of wholes) of the mining technology. An important indicator is the content of clay minerals in the deposit and in the obtained product.

To calculate the destruction productivity, research results and practical data on the relationship between the hydromonitor stream and the rock, the radius of erosion and the change in the dimensions of the production over time, and the nature of formation destruction are necessary.

The process of rock movement in an underground chamber is determined depending on the mining scheme, the angle of inclination of the formation, the size of the chamber, and the properties of the destroyed rock. For designing, the results of the study of the schemes of transportation of the hydraulic mixture in the underground chamber are necessary.

The initial data includes the general technological scheme of production, the component processes of the technology, and auxiliary services. Working technological parameters and the permissible range of fluctuations for each process are given, as well as recommendations on the procedure for starting production, normal and emergency stop.

The mathematical description of processes and equipment is given in a form suitable for practical calculations. It is based on experimental data. Recommendations for choosing the optimal equipment models are also needed.

Practical recommendations for the design of well equipment. Optimum dynamic characteristics of the jet and the best possible compactness of it can be ensured by: giving the underflow channel a smoother contour and installing tranquilizers in the nozzle of the hydromonitor to extinguish the almost inevitable turbulence, in particular, for short hydromonitors it is advisable to use tranquilizers in the form of a needle-shaped streamlined rod located directly in the nozzle. The best hydrodynamic properties of the jet are ensured by the formation of a water flow in the barrel of the hydromonitor, equipped with a honeycomb-type stabilizer with an even number of square cells, provided that the size of the side of the square of each cell is 0,25 of the diameter of the barrel channel.

The ratio of the sizes of the trunk and the tranquilizer must be within the following limits: the length of the longitudinal plates of the tranquilizer is equal to 2,5-3 diameters of the trunk channel; the section of the flow channel of the hydromonitor trunk between the tranquilizer and the nozzle is equal to 3-4 diameters of the trunk channel; the section of the flow channel of the trunk from the rotary joint to the stabilizer is equal to two diameters of the trunk channel. Then the total length of the trunk of the hydro-monitor will be equal to 7,5-9,0 diameters of the trunk channel.

The choice of the type of nozzles of the hydromonitor must be carried out in accordance with the following established provisions: nozzles with a rounded entrance have a lower resistance, that is, a higher coefficient of flow, than nozzles with sharp entrance edges; a cone-shaped nozzle has a higher flow rate and a lower jet compression ratio compared to conical nozzles. For nozzles of mine-type hydromonitors with a diameter of 20-30 mm for a pressure of 2-10 MPa, the length of the cylindrical part of the nozzle is recommended to be equal to four diameters.

Ways to increase the suction area of the pulp lifting device. The most effective way is to use a flexible suction tip, the position of which is controlled from the surface. The flexible suction can be made of a reinforced hose and telescopic articulated pipes. As the hole is worked out, the flexible sucker is fed forward, ensuring a constant consistency of the hydraulic mixture, complete extraction of ore from the chamber and reduction of the length of the overall production of the chamber.

For the industrial extraction of zeolite-smectite tuffs of the Rafalivskoye deposit, a technological scheme is proposed, in which it is advisable to open the reservoir by a one-well mining method with a counter strike. It is expedient to develop the site with single chambers, leaving inter-chamber wholes. For the conditions of this area, the distance between wells is assumed to be 30-35 m.

Water supply is carried out according to the reverse scheme. The drained water enters the sump and is then supplied to the nozzles of the hydromonitors by pumps (with a capacity of 280-290 m^3/h at a pressure of 2,9-3,9 MPa). Replenishment of water losses is carried out from two artesian wells, equipped with deep pumps with a capacity of 40 m^3/h. The hydromix is fed to the leaching map by dredges with a capacity of 342 m^3/h, and then the mined rock is transported to the receiving hopper of the factory.

The deposit is divided into blocks with reverse working. In the spent block, dismantling works and repayment of productions are carried out, in the working block - tuff mining, and in the preparatory block - drilling and equipment of production wells and laying of block pipelines.

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FEATURES OF REGENERATION OF LOW-DOSE HYDRATE FORMATION INHIBITORS

Technological processes of oil and gas extraction can be complicated by the formation of man-made gas hydrates. The main way to prevent hydrate formation is the use of inhibitors of this process. At the same time, methanol is the most effective inhibitor. However, methanol is a strong poison. In addition, its significant volatility leads to significant losses in technological processes.

One of the alternatives to methanol is low-dose inhibitors of kinetic action (for example, polyvinylpyrrolidone (PVP), polyvinylpiperidone (PVPip), polyvinylcaprolactam (PVCap), and polyvinylazacyclooctanone (PVACO) [1]). Such inhibitors of hydrate formation belong to the category of "ecological" for the environment, which reduces risks during their transportation and storage. Kinetic inhibitors have a low corrosion rate and are compatible with reservoir fluids [2].

However, the physical properties of these substances determine the expediency of their use in a mixture with other inhibitors [3,4] (for example, ethanol). Using ethanol as a hydrate formation inhibitor will help reduce the negative impact on the environment and people. It will be especially relevant in the process of developing offshore gas and oil deposits. At the same time, relatively low thermal stability of known hydrate formation kinetic inhibitors requires improvement of technologies for their regeneration from aqueous solutions.

At the moment, the method of methanol regeneration from a water-methanol mixture by means of rectification has become widespread. However, the maximum allowable heating temperature, for example, PVP, PVCap is 150-180 °C. That is, it is significantly higher than the boiling point of lower alcohols (ethanol 78 °C) [1]. However, their regeneration by the method of hydrate

concentration can be quite promising. This technology is based on the property of gas hydrates to displace all molecules except water and hydrate-forming gas from their crystal lattice [5].

In the course of experimental studies, the peculiarities of the morphology of gas hydrate formed in solutions of a mixture of hydrate formation inhibitors of kinetic and thermodynamic action were analyzed depending on their concentration and thermobaric parameters (Fig. 1, 2).

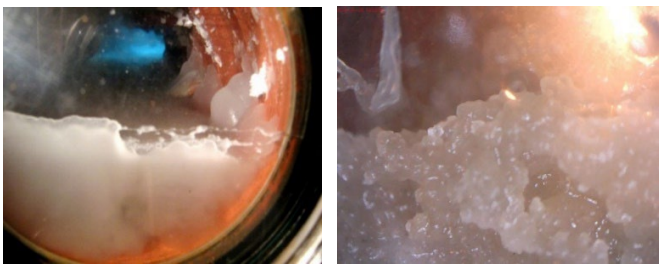

Fig. 1. The appearance of the gas hydrate formed in a solution of 0,5% by mass. PVCap and 55% ethanol (gel-like)

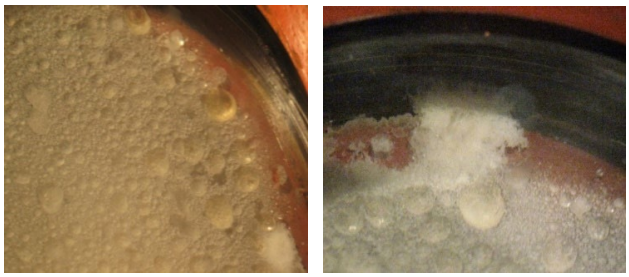

Fig. 2. The appearance of the gas hydrate formed in a solution of 0,5% by mass. PVCap and 10% ethanol (whiskers)

Taking into account the morphology of the formed solid phase, a schematic diagram of the experimental and industrial installation is proposed (Fig. 3). The description and principle of action of its laboratory analogue are given in [6].

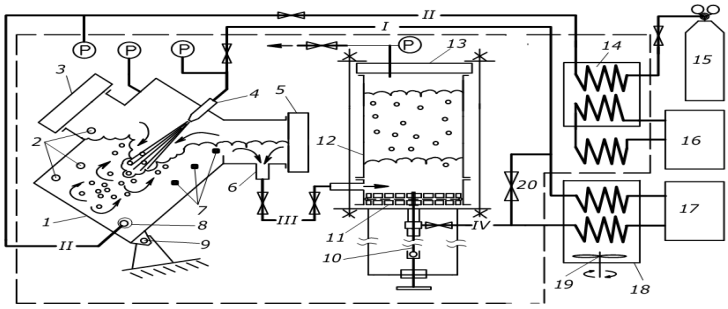

Fig. 3. Schematic diagram of the experimental and industrial plant for concentration of the inhibitor solution: *1* - reactor; *2* –- temperature sensors; *3*, *5*, *13* - flanges; *4* - jet device; *6* - fitting; *7* - control devices; *8* - bubbling device; *9* - support; *10* - hydraulic press rod; *11* - a piston with a filter element; *12* - separator body; *14*, *18* heat exchangers; *15* gas source; *16* refrigerating unit; *17* - pump; *19* - stirrer; *20* - bypass valve;
streams: I solution of inhibitors; II hydrate-forming gas; III liquid-hydrate mixture

The process is implemented as follows. The aqueous solution of the mixture of inhibitors enters reactor *1*. After connecting the installation to the gas source, pump *17* (Fig. 5) is turned on, which ensures liquid circulation along the line: reactor *1* - separator *12* - heat exchanger *18* (section 1) - pump *17* - heat exchanger *18* (section 2) - jet apparatus *4* - the reactor. Water in this process, in addition to being part of the gas hydrate, performs the function of a refrigerant to remove heat from the reaction zone.

Gas in the process of hydrate formation is in excess. The pressure in the reactor is kept constant. Its supply is carried out automatically by bubbling into the lower part of the reactor after the pressure drop in the reactor as a result of the inclusion of part of the gas in the composition of the gas hydrate. Propane is used as a hydrate-forming gas. The temperature in the reactor for the process is maintained no higher than minus 28 °C. According to preliminary calculations, it is technically acceptable to concentrate the aqueous solution of the kinetic inhibitor and ethanol to a concentration of the latter of 70%.

After maximum filling of separator *12* with gas hydrate mass, the process will stop. Next, piston 11 with a built-in filter element compresses the contents of the separator. As a result, a concentrated solution of a mixture of inhibitors is squeezed out of the gas hydrate through the filter element. Next, the heat carrier (water) with a temperature of 60 - 95 °C (not indicated on the diagram) is supplied to the separator by a pump. Melting of gas hydrate and accumulation of high-pressure gas occurs. The gas is removed from the separator, cooled and liquefied. Water after melting the hydrate will contain a minimal amount of inhibitor. Thus, gas-hydrate concentration technology can be an effective way of regenerating the spent aqueous solution of a mixture of PVCap and ethanol.

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METHOD OF MANUFACTURING OF DRUM MILL LINING PLATE

The lining of the inner surface of the drum mill not only protects the surface of the drum from wear but also largely determines the quantity and quality of the raw material, the duration and ener-

gy consumption of the ore grinding process [1, 2]. Therefore, a large number of works are dedicated to the creation of wear-resistant rubber linings that combine the effects of wear resistance of metal, lightness and deformability of rubber in their design [1-5].

At the same time, issues of the technological sequence of manufacturing composites (rubber linings reinforced with discrete wear-resistant metal elements) remain neglected. The issues of complexity, technical and economic feasibility, cost of positioning and fixing discrete wear-resistant elements in the rubber "body" of composite linings remain open. Here it is worth noting that the lining plates classically have significant dimensions and are produced individually, therefore it is also important to ensure the predicted joint reliability in relation to the physical and mechanical properties of the received samples.

The purpose of developing a method of manufacturing a lining plate of a drum mill is to manufacture a high-quality, with predicted characteristics, wear-resistant rubber lining plate of a drum mill under the condition of minimal labor costs for reinforcement and positioning of metal discrete reinforcing elements along the working surface of the lining plate.

Fig. 1 shows a mold consisting of a lower part *1* and a cover *2*, which have the possibility of a hermetic connection. Cover *2* provides for the installation of a sprue system *3*, which is a metal-embedded element with a system of holes *4*. Four wheel blocks (hub and wheel) *5* are attached to the lower part of mold 1 for moving along the rails 6, respectively to the proposed technological process. For the hermetic connection of the lower part *1* and cover *2* of the mold, a tightening mechanism *7* and a sealing lock *8* are provided.

The method of manufacturing the lining plate of the drum mill [utility model application u202301453 dated 04/04/2023] is as follows. The prepared mold with the sprue *3* installed in the open cover *2* is installed on the rails *6* by means of the wheel blocks *5*, and fed to the place of batch dosing of discrete metal elements (see Fig. 1). With the help of a dispenser *//**, a defined portion of discrete metal elements *10* is placed in the inner cavity of the lower part 1 of the mold in bulk, and their preliminary manual planning is performed. After that, the mold is moved along the rails 6 to the place of stationary installation of the electromagnets *11*, which are located below the lower part of the mold *1* according to the profile of the future lining plate (Fig. 2). The elastic material is inserted into the sealing lock *8* and the inner cavity of the press mold is sealed by connecting the lower part *1* and the cover *2* with the help of the tightening mechanism *7*. Then the injection mechanism (see Fig. 2) is heated to a temperature of 80 up to 100 ºC with a rubber mixture (see Fig. 2). The injection mechanism is installed directly on cover *2* to minimize the loss of the rubber mixture in the channels. Electromagnets *11* are turned on that ensure the final position and fix discrete metal elements *10*. Then the rubber mixture heated to a temperature of 80 to 100 ºC supplied by the pumping mechanism.

The lower location of the discrete metal elements *10* in the inner cavity of the part *1* allows to ensure their stable and fixed position during the dynamic impact on them of the jets of the rubber mixture *12* (see Fig. 2). The inner cavity of the mold is completely filled with rubber mixture, after which the injection device is disconnected and electromagnets *11* are turned off. The mold with the future lining plate is moved to the autoclave. The vulcanization of the rubber mixture of the lining plate takes place in the autoclave. The process is accompanied by maintaining the pressure in the middle of the autoclave in the range from 3 to 6 atm., a temperature of 143 ºC, and a holding time of at least four hours at the specified parameters.

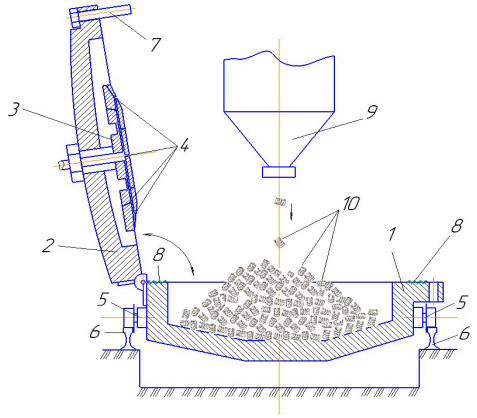

Fig.1. The press mold in open position, installed on the rail course and located at the place of dosing of metal and discrete elements

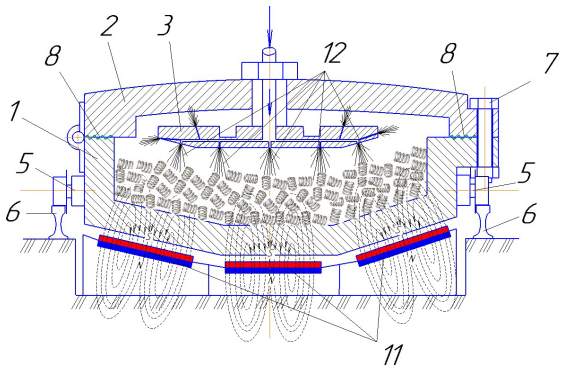

Fig. 2. The press form is relocated to the stationary electromagnets and the heated rubber mixture is supplied under pressure

The last stage of manufacturing the lining plate of the drum mill is stopping the vulcanization process, removing the mold from the autoclave, cooling it, disassembling the tensioning mechanism *7* and removing the finished lining plate reinforced with discrete metal elements *10*.

At the same time, the metal sprue *3,* which is vulcanized in the lining plate will later perform the functions of an embedded fastening element of the lining plate to the inner surface of the mill drum.

The proposed method of manufacturing rubber lining plates combines the advantages of disassembly design, reusable mold, with pressure casting, heated to a temperature of 80 to 100ºC with a rubber mixture.

This makes it possible to reduce the cost of the manufacturing process with sufficiently high-quality indicators of the final product and additionally provides opportunities for reinforcing the rubber lining plate with metal discrete wear-resistant elements *10*.

The proposed technology provides for the possibility of positioning, fixing and dosing discrete reinforcing elements *10* for lining plates with different configurations of working surface.

The process of positioning, fixing and dosing can be carried out in automatic mode, which significantly increases the predicted physical and mechanical properties of lining plates, determines their uniform and uniform operation.

It is also worth noting the rational position of the mold during casting, which will contribute to the additional pressing and fixation of discrete elements *10* by jets *12* of the rubber mixture during its supply under pressure, and the use of the embedded fastening element *3* as a sprue, which also ensures minimal rubber due to rational installation of the injection device.

Thus, the application of the proposed useful model will make it possible to achieve high-quality, with predicted characteristics, production of wear-resistant rubber lining of a drum mill under the condition of minimal labor costs for reinforcement and positioning of metal discrete reinforcing elements along the working surface of the lining plate.

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COMBINED TECHNOLOGY FOR DEVELOPING QUARTZITES USING PLASMATRONS

Ferrous quartzites of Ukraine represent an important factor in the formation of the country's budget [1]. When enriched, magnetite quartzites reach up to 70% or more iron in concentrate and are an important strategic raw material [2].

In the industrial conditions of YuGOK and INGOC the prospects of using a combined technology for drilling blocks of strong ores were proven [3,4]. The advantage of this technology is the ability to form downhole charging cavities of a given configuration. The authors of the work [5] proved that the combined technology of well drilling has been working at YuGOK for more than 70 years. Fire drilling machines were introduced here for the first time. Thermal drilling machines were presented here for the first time. The borehole is thermally expanded from a diameter of 250 mm to 360 mm. From one meter of borehole, the yield of rock mass is 67,36 m^3. These machines

are metal intensive and difficult to operate. The technology for breaking hard ores in open-pit mining cannot be implemented in underground mining. There are a number of reasons. We need new, more mobile equipment and new principles of thermal destruction of rocks.

At IGTM NAS of Ukraine, single-chamber plasmatrons were developed as a working part of a mining machine. Plasma generators are a flexible tool in terms of thermal, energy and operational parameters. They are simple in construction. The plasmatron can produce temperatures above

4000^0C. Today in the mining industry, plasmatrons are the only means of creating chamber with a diameter of 500 mm or more in hard ores. With the help of plasma, almost any endothermic reaction in rocks can be carried out. The main thing is to learn how to control the plasma torch. The simplicity of the plasmatron of design allows them to be manufactured in any mine.

In the underground conditions of mines, when developing ferruginous quartzites, mechanical drilling machines are used. They make it possible to obtain borehole of the same diameter along the entire length and create charging cavities in the form of cylinders. For boreholes, the diameter of the mouth and the diameter of the charging cavity are the same. As the diameter of the boreholes increases, the efficiency of the blast decreases.

The IGTM NAS of Ukraine has developed a combined technology for drilling blocks of ferruginous quartzite: drilling small-diameter boreholes with mechanical machines using an expanded grid, followed by their expansion with plasma heat generators. This technology makes it possible to reduce the volumes of drilling work and adjust explosive charges according to the height of the block. This allows for more efficient management of blasting operations. The diameter of each cavity can be 3-6 times greater than the diameter of the pioneer boreholes. This forma of the charging cavity creates the effect of blocking the boreholehead. This allows the explosive charge to work better on the rock massif. The chambers in various technologies allow the charge to be dispersed in the massif and the destruction of strong ores to be carried out due to shear and stretching stresses. This makes it possible to destroy a splices of mineral raw material and separate magnetite from the rock.

The plasma method makes it possible to create charging cavities with a volume larger than the volume of the explosive charge placed in them. The effect of the blast is intensified due to the fact that the blasting gases transfer the blast energy to a much larger surface of the rock surrounding the charge [6].

A theoretical assessment of the change in specific of blast energy when creating a chamber expansion in boreholes previously drilled with mechanical machines is given in article [7]. When creating a chamber, the energy emitted into the rock mass changes compared to the blast of a cylindrical charge with a diameter equal to the diameter of the chamber. The presence of air cavities between the explosive charges and the wall of the chamber changes the mechanism of the blast and the explosive charge works more efficiently.

In work [8], a mathematical model for creating a chamber was developed. The analysis was carried out in comparison with the experiment. The shapes of the chamber at various points in time are presented, model and experiment. The tables show the results of calculating the parameters of the boiler cavity of the model and experiment for magnetite and hematite-magnetite quartzites at the Ordzhonikidze mine in Krivoy Rog.

The plasma method of borehole expansion has been tested in magnetite quartzites of complex structure with varying degrees of metamorphism in the mines of Krivbass. The work [9] presents the technique and technology for expanding borehole in underground conditions.

Conclusions

Based on the developed mathematical model of the process of formation of a chamber in hard rocks, the results of the dynamics of changes in the shape of the chamber at different points in time were obtained.

Comparison of the obtained theoretical results with experimental data showed satisfactory convergence (within 5-7%).

The creation of chamber expansions close to a spherical shape allows, with a smaller charge mass, to provide specific energy as in the explosion of a cylindrical charge with a radius equal to the expansion radius.

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METHODS FOR PREDICTION OF DISTURBED ZONES AND DYNAMIC PROCESSES IN SEDIMENTARY ROCKS

According to the Mining Encyclopedia (1986), dynamic phenomena in underground workings are sudden movements of rocks near the mine workings with high speed and a strong dynamic ef-

fect. Thus, dynamic phenomena are the result of the occurrence of rock pressure and the pressure of fluids contained in rocks. Dynamic phenomena include rock bursts, drift sands, rock falls, etc.

To prevent or reduce the intensity of dynamic phenomena, various methods of physical, chemical and technological influence on the rock mass are used, which make it possible to change its stress-strain state.

When in the middle of 50s of the last century, such a new phenomenon as outbursts of sandstones at depths of more than 700-800 m appeared in the Donetsk coal basin of Ukraine, national programs were created. Dozens of institutes and production organizations were involved, to solve this problem. IGTM NAS of Ukraine was one of the leading institutes dealing with this problem and now with a high degree of probability we can predict the conditions for the occurrence of rock outbursts not only in the Donetsk coal basin, but also at other mining enterprises [1-4].

In the IGTM NAS of Ukraine was developed method of side illumination in petrography that allows us to see structural defects in clear minerals, especially in quartz (Ukrainian patent No. 125699). Later, as a result of studies of clastic quartz grains of carboniferous sandstones, which host coal seams, from 1 to 6 main tectonic events were identified in the Donetsk coal basin (Ukrainian patents No. 51207, No. 34397), (Fig. 1). The maximum number of plastic microdeformations was established in the central, most damaged part of the Donetsk basin.

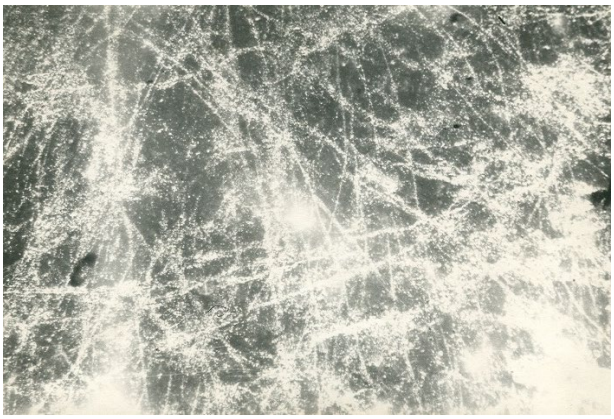

Fig. 1. Four systems of microdeformations in quartz grain of carboniferous sandstone of the Donetsk-Makeevsky region of the Donetsk basin

Analysis of tectonic events in this region showed the evolutionary cyclicity of phase subsidence-uplift and 6 revolutionary tectonic events - large earthquakes that left “traces” in the detrital grains of quartz - a strong but fragile rock-forming mineral of the coal-bearing sandstones of the Donetsk basin.

There are many different types of deformations left in quartz grains, but the most common are Boehm stripes - dislocation zones where gas was penetrated and preserved in the form of gas inclusions.

Thus, a feature of the Donetsk coal basin is the increased density of sediments that have undergone not only subsidence and lithostatic compression, but also uplift. For this reason, the rocks of

this basin have significantly lower porosity and permeability, but greater strength, in contrast to similar deposits in the Dnieper-Donetsk basin or other coal basins.

The decrease in porosity and permeability of rocks towards the central part of the Donetsk basin demonstrates areas where the mobilization of sediments, as well as their thickness, was maximum. In this sense, the rocks of the central part of the basin, together with the adjacent areas, have minimal porosity and permeability, and they belong to the middle and late substages of catagenesis. Coals are also transformed to a greater extent, since in the deep parts of the basin the heating was higher, affecting the degree of coalification and structuring of the coal matter. The uniaxial compressive strength increases towards the central part of the basin, changing values by virtually an order of magnitude, from several tens of MPa to 150-200 MPa.

Thus, knowing the boundary values of the reservoir and physical-mechanical parameters of the carboniferous coal-bearing deposits of the Donetsk basin, we know what properties and dynamic processes we may encounter when mining coal in different areas of the basin. In addition, we understand at what modern depths significant changes in the properties and state of rocks and minerals will occur, what problems may arise and what measures need to be taken in order to avoid negative consequences as much as possible and maintain the safety of miners at the proper level.

It can be unequivocally stated that any energy impact on a substance, in appropriate volumes, can lead to a change in the structure and properties of this substance. For the most effective influence on the properties of a substance, there is an optimal density of microdefects for the structure of a given substance [2-3]. This means that knowing the lower and upper limits of this density, we can most effectively predict gas-dynamic phenomena, the properties of these rocks, or control these properties.

It should be noted that defect formation at the microlevel in sedimentary rocks has been poorly studied in comparison with other deformations. Such dynamic phenomena as outbursts of coal, rock and gas, shooting, rock bursts at deep levels of mines are becoming frequent phenomena, reflect the stressed state of the rock mass and are a consequence of the relative instability of the structural parameters of rocks.

As a result of these impacts, the stability of the structural parameters of the rock is disrupted. From this moment on, various gas-dynamic phenomena can occur in the rock massif, for the implementation of which only minor energy impacts are sufficient - blasting rocks in neighboring faces, the operation of a combine and other seismic-like impacts.

With a further increase in paleodepth, and, accordingly, thermobaric influences, the accumulated energy is realized in a change in structure. The rock becomes stronger, its physical and mechanical properties change, and phenomena such as outburst hazard, peeling, and chipping disappear. At the same time, more and more areas with a quartzite structure appear, especially in areas with a

small amount of cement (less than 5%), the structural parameters become equalized due to the destruction of the largest grains and a decrease in potential energy.

This destruction, according to the empirical data obtained, does not occur simultaneously, but as a result of several transition stages. Initially, a significant amount of elastic energy accumulates in the detrital grains, which is realized during a progressive process into plastic deformation. Plastic microdeformations begin to appear, accumulate and transform in the grains: Boehm stripes, plates and deformation belts, irrational and crumpled quartz. Subsequently, with increasing external influences, due to lithostatic, tectonic and temperature influences (mainly), according to the most energetically unstable plastic deformations, a discontinuity occurs, in other words, a brittle deformation, expressed in the crushing of grains into blocks, granulation and the emergence of an energetically more stable to external influences of the structure.

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STRATEGIC DIRECTIONS OF INNOVATIVE DEVELOPMENT OF THE COAL INDUSTRY ON THE EXAMPLE OF THE LVIV-VOLYN COAL BASIN

The development of the national coal industry on an innovative basis is one of the main directions of the transformation of the energy industry into a modern, economically efficient link of the national economy. This issue is actualized by the high degree of dependence of the national economy on the import of fuel and energy resources, which leads to a decrease in the overall level of competitiveness of national products. That is why, at the current stage, it is necessary to research and develop innovative ways of developing the national fuel and energy complex of Ukraine as a whole and its important component - the coal industry, coal itself, as an energy resource, is the most important source of energy. There are significant reserves of this raw material in Ukraine, which ensure a long-term perspective of the coal industry, justifying the corresponding priority of the national policy regarding the coal industry. Creating conditions and ensuring sustainable development

of the national coal industry based on innovative development will strengthen the stability of the national economy as a whole.

In the 50s of the last century, a decision was made to build the Lviv-Volyn coal basin in order to provide the energy industry of Western Ukraine with raw materials. Industrial development of the Lviv-Volyn coal basin was started in 1950. On December 27, 1957, the first tons of coal went uphill from the depths of mine № 2 Velikomostivska. This day is considered the beginning of the coal industry of Lviv Oblast. 3 From 1954 to 1964, 18 mines with a total design capacity of 8,9 million tons were put into operation in the basin, in 1965-1974, 2 more mines with a capacity of 1,7 million tons were built, and in 1978, mine № 10 "Velikomostivska" was built.

The potential of the Lviv-Volyn coal basin is far from exhausted. Along with thermal coal, which is currently mined, deposits of coking coal were discovered, which also extends to the territory of Zhovkiv district of Lviv region. The construction project of the "Lubelska № 1-2" mine, which is of strategic importance in the conditions of a critical shortage of coking coal, envisages the creation of 2,700-3,000 jobs. The cost of the project is 930 million US dollars (construction), payback from the moment of launch, re-equipment - two years. Reserves of the "Lubelska" deposit amount to 277 million tons. The problem of the construction of the "Lubelska" mine is the lack of real sources of financing, since the project must be implemented with the funds of private investors. In recent years, the coal industry of Ukraine has been in a state of deep stagnation and continuous aggravation of systemic problems, which can significantly shake Ukraine's energy security. The complete underdevelopment of reproductive processes in the industry, which is partially shown by the example of Lviv Coal State Enterprise, extremely unsatisfactory material and technical support of coal mining enterprises, and difficult engineering and geological conditions inhibit the development of the energy base of Ukraine's economy.

Coal mined at the mines of Lviv Coal has a sufficiently high ash content (the higher the ash content, the lower its efficiency).

In this regard, a large part of the mined coal needs additional enrichment, which in turn increases its cost price. Another enterprise - PJSC "Lviv Coal Company" is engaged in beneficiation of coal from the mines of SE "Lvivvugilya".

This company has a monopoly position on the market and dictates the price of the coal beneficiation service. In connection with this, SE "Lvivvugillia" loses a large part of the profit. Such costs could be avoided by building a beneficiation plant at the facilities of the Lviv Coal State Enterprise.

Analyzing the indicators of the financial and economic activity of SE "Lvivvugilya" for 2010-2022, a number of conclusions can be drawn.

1. The volume of production of coal products is gradually decreasing. At the same time, the number of employees per enterprise is decreasing.

2. The level of depreciation of fixed assets is high (more than 70%), which increases by 1-2% every year. The rate of recovery of fixed assets lags behind the rate of depreciation by 5,6% over the past five years. The results of the analysis of the indicated indicators indicate the insufficiency of financial resources for the restoration of production capacities of mines and unsatisfactory financing of innovative coal mining technologies, the introduction of which is necessary for the modernization of technological processes and equipment.

3. The company owes significant amounts of long-term liabilities (loans). More threatening is the situation with the presence of current liabilities, the amount of which is systematically growing at a high rate.

4. SE "Lvivvugilya" is accumulating uncovered losses, the amount of which is constantly increasing. The enterprise receives losses every year, the cause of which is the high cost of coal and the price of coal products, which is 2.6-1.2 times lower than the cost. The accumulated amount of losses indicates the growth of current liabilities, the lack of profit as a source of enterprise development, makes it impossible to increase capital investments in the preservation of production capacities, and the introduction of innovative technologies.

The strategic directions of the innovative development of the Ukrainian coal industry can be determined on the basis of:

• rational use of the subsoil at the expense of radical, high-level organizational and technological modernization of production;

• creation of full-fledged market conditions for increasing the financial stability of enterprises, overcoming their unprofitability under the effective regulatory role of the state;

• deep structural conditions of industry and enterprise management;

• consistent implementation of scientifically based coal mining processes, accumulation and attraction of investment resources.

Conclusions and prospects for further development. The coal industry remains a national priority in the economy of Ukraine, and its economic efficiency and stable dynamic development are related to the formation of an effective innovation policy. For further innovative development of the industry, it is necessary to develop and implement a system of measures to increase the market competitiveness of coal products, to introduce the latest scientific and technological developments of domestic science into the production of knowledge-intensive products produced at joint enterprises of the fuel and energy complex with the involvement of foreign specialists, to increase the involvement of private capital in the activity subjects of the coal industry.

At the state level, it is necessary to decide on the development of promising coal deposits, especially in the Western region of Ukraine, through the construction of new mines and the identification of sources of construction financing. A worrisome factor is the decrease in the number of em-

ployees at the enterprises of Lviv Coal State Enterprise, which indicates, in particular, the general trend of the outflow of workers from the difficult and dangerous profession of a miner, due to an unsatisfactory level of wages and late payments. It is necessary to pay attention to employment in coal regions and the possibility to fill jobs in the future in case of construction of new coal enterprises.

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TECHNOLOGICAL SOLUTIONS OF DRILLING WASTE DISPOSAL

Waste from the drilling of well № X in the Bukhtivetskyi section of the Bytkiv-Babchynskoye field is drilling waste water and rainwater, drilling mud, particles of drilled rock, and surplus cement solutions.

The volume of waste when drilling a well will consist of the volume of removed rock - 227 m^3, the volume of solution for testing the well - 90 m^3, the volume of spent washing fluid - 587 m^3, the volume of drilling wastewater - 1174 m^3. Thus, the volume of waste when drilling a well will be 2285 m^3.

The first sedimentation barn of the well № X is constructed in such a way that the excess liquid flowing through the concrete trays from the cleaning unit and the mud preparation unit and from the well mouth overflows into the second barn for water settling. The second barn is built in such a way that the excess liquid that flows from the first is poured into the third, from which the settled water will be pumped out for reuse. Along the perimeter of the barns, a 0,5 m high embankment of site soil is made.

A colloidal-chemical anti-filtration screen is applied to the bottom and walls of the barn to prevent harmful substances from entering the soil (Fig. 1). Such a screen is built on the basis of an aqueous suspension of hydrolyzed polyacrylamide (GPAA) and bentonite clay

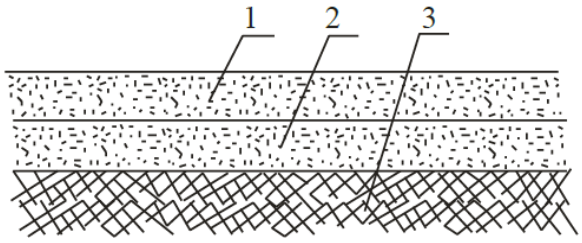

Fig. 1. Anti-filtration screen of sludge barns: *1* - polymer-clay layer; *2* - diffusion layer; *3* - natural soil [1]

Three earth storage barns with a volume of 782,1 m^3 each are designed for separate collection of sludge, spent washing liquid and wastewater and well test products.

The disadvantage of such a solution is that such barns will occupy significant areas.

It is proposed to apply a technological solution to the disposal of drilling waste after separating the liquid phase from it. In the calculations, it is assumed that 37% of the water phase can be removed by dehydration.

The author proposed to build a monolithic vertical anti-filtration fence of the "wall in the soil" type from soil-cement elements.

It is proposed to take the distance between the centers of adjacent soil-cement elements as 0,8d (d is the diameter of the soil-cement elements). Soil-cement elements are proposed to be manufactured by the drilling method [2].

The technology of arranging the elements consists of crushing the soil massif, injecting cement (binder) into the soil, and mixing the soil with cement by the working body of the drilling machine.

As a result of these operations, a pile is formed with a fixed diameter, which is determined by the size of the equipment.

A significant advantage of using soil-cement elements is that the most favorable environment for their arrangement is water-saturated soils, as well as those located below the groundwater level. Soil cement, despite its high porosity, has an abnormally high water resistance.

The improved properties of soil cement are achieved due to the small content of clay particles in the soil, which is included in its composition.

A significant role in this is played by the alkaline reaction of the environment, a small amount of easily soluble salts, easy dispersion during water saturation due to water-soluble bonds between particles.

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THE ENERGY EFFICIENCY INCREASING OF THE SYSTEM «ROCK EXCAVATOR - POWER LINE» IN CONDITIONS OF THE UKRAINIAN MINING AND ORE ENTERPRISES

A large portion of rock excavators working in the quarries of Ukraine are equipped with a five-machine system "generator - motor" [1]. In this system, during the start-up period, the primary synchronous motor is directly connected to the power supply system. This technical solution causes seven-fold starting currents, which create 49-fold electrodynamic forces, which leads to the rapid accumulation of fatigue damage in the windings of the synchronous machine and the power transmission line. Therefore, the existing technology imposes strict restrictions on the number of direct starts of the motor - no more than 3-4 times a day, which makes it possible to maintain the aggregate in a working condition.

This approach contradicts the principles of energy efficiency, because during periods of technological pauses (for example, waiting for technological transport, which can reach a total of up to 4 hours of working time per day), the generator group of the excavator works in idle mode with electricity consumption from the network. During non-productive waiting periods, the power consumed by excavators is: EKG-8 - 110-120 kW, EKG-10 - 130-150 kW, ESH-10/70 - 200 kW. This power is converted into heat and carried out by fans into the atmosphere. At the same time, the windings heat up, the insulation ages, the bearings wear out, the brushes wear out, and the collectors on the generators are wiped. The engine resource of the unit is unproductively consumed and reduced.

In addition, the problem of reactive power generation by a synchronous motor is added both in the working cycle and during periods of technological pauses at idle speed.

The existing problem is effectively solved by a smooth (shockless and therefore harmless, both for the electrical equipment of the excavator and for the power supply line) start of the generator set at the nominal current with the help of a device for operational control of the conversion unit of the rock excavator, which is provided by patents of Ukraine [2, 3]. This device realizes the immediate shutdown of the aggregate operating for more than 0,5-2 min. in idle mode, which saves electricity.

After the end of the technological pause, the device realizes shock-free (smooth and harmless) acceleration of the aggregate to the nominal speed. The acceleration time of the aggregate is: 20-25 seconds for the EKG-8 excavator; 25-30 sec. - EKG-10; 45-50 sec. - ESH-10/70. There are no starting currents and dynamic shock loads in the "generator - motor" system and the power transmission line.

A shock-free start is ensured by the fact that an inductive-capacitive converter with a three-phase rectifier is connected to the armature circuit of the generator in the multi-machine unit of the excavator, which contains an alternating current machine and direct current generators on one shaft, during the start-up period. Such a converter allows to synchronize the voltage levels at the output of the uncontrolled rectifier with the nominal voltage of the armature circuit, and on the other hand, it fully preserves its functionality in case of network voltage dips.

The problem of generating excess reactive energy is solved by applying a suitable device to regulate the excitation current of the synchronous motor both in the working cycle and during periods of technological pauses. This is achieved by monitoring the generated reactive power and automatically maintaining it at a given level, down to zero when the power factor is equal to one.

Currently, the effectiveness of the proposed options is confirmed by the positive experience of implementation on excavators in the conditions of the Southern mining and ore-dressing plant, which significantly increased the technical and economic performance of rock quarry excavators and power supply lines.

The effect of the implementation of the soft start device has been confirmed by the specialists of the technological and electrical equipment operation services of the Southern mining and ore-dressing plant.

They note that the energy efficiency of the excavator and the power supply system has significantly increased. The expected economic effect is more than UAH 1,700,000 per year due to electricity savings and at least UAH 800,000 due to the extension of the aggregate's trouble-free operation. The payback period of the project is expected to be 6-7 months.

Conclusions

Therefore, the application of the proposed method and device for soft start of the generator set of the excavator allows to eliminate shock currents at the time of connecting the alternating current machine to the power supply network, increase their non-accident life, improve energy indicators during the period of acceleration of the generator set, and eliminate the impact on the power supply system of starting loads.

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SUSTAINABLE COPPER MINING: BALANCING RESOURCE EXTRACTION WITH ENVIRONMENTAL AND SOCIAL RESPONSIBILITY. CASE STUDY

The mining industry has been a cornerstone of human progress and economic development for centuries, providing the raw materials necessary for infrastructure, technology, and countless other essentials of modern life. However, the environmental and social costs associated with conventional mining practices have raised serious concerns. In response to these challenges, sustainable mining has emerged as a guiding philosophy that seeks to reconcile the imperative of resource extraction with the pressing need to protect our planet and foster social well-being.

One of the fundamental principles of sustainable mining is environmental responsibility. This involves minimizing the environmental footprint of mining operations. Strategies encompass the reduction of water and energy consumption, the efficient management of waste, and the prevention of pollution. Sustainable mining aims to rehabilitate and restore mined areas to their natural state once extraction is complete, allowing ecosystems to recover and flourish.

Social responsibility is equally integral to sustainable mining. Respecting the rights and well-being of local communities and indigenous peoples is paramount. This includes recognizing their land and cultural rights and promoting community engagement, consultation, and participation in decision-making processes. Sustainable mining operations aim to enrich the communities in which they operate by providing jobs, supporting local businesses, and contributing to regional development. Moreover, they work toward fair and equitable distribution of benefits and revenues.

Economic responsibility within sustainable mining means creating economic opportunities for local communities. This is achieved through job creation, support for local businesses, and contributions to regional development. Economic benefits should be shared equitably among stakeholders, ensuring that wealth generated from mining is not concentrated in the hands of a few, but rather supports the broader community.

Resource efficiency is central to sustainable mining. Companies seek to maximize resource recovery while minimizing waste. Techniques and technologies are employed to optimize processes

and reduce resource consumption. Responsible water and energy use are paramount to decrease the environmental impact of mining.

Prioritizing the health and safety of workers is a fundamental aspect of sustainable mining. Ensuring that mine workers have safe working conditions, receive adequate training, and have access to healthcare is essential. This commitment safeguards the well-being of those directly involved in mining operations.

Case study. Trends and some key initiatives of the world's largest producers of copper.

Chile is the world's largest producer of copper, and the copper mining industry plays a crucial role in the country's economy. Copper mining contributes significantly to government revenue and exports.

Chile has made efforts to promote sustainable mining practices within its copper mining industry. Some key initiatives and areas of focus include:

- The Chilean government has implemented environmental regulations to mitigate the impact of mining activities on the environment. These regulations include requirements for water management, waste disposal, and emissions control.

- Water is a critical resource in mining operations, and sustainable water management is a priority in Chile's copper mining industry. Companies are often required to develop water management plans and reduce water consumption.

- Chile's mining sector has been working to improve energy efficiency by adopting cleaner technologies and renewable energy sources, such as solar and wind power.

- Sustainable mining practices also involve engaging with local communities and addressing their concerns. This includes consultation, social development programs, and initiatives to benefit the communities near mining operations.

- Proper management of tailings, the waste materials produced during mining, is a significant sustainability concern. Chile has implemented regulations to improve tailings dam safety and minimize the risk of environmental accidents.

Peru is one of the world's top copper-producing countries. Copper mining is a crucial industry for the country's economy, contributing to government revenue and employment.

In recent years, Peru has made efforts to promote sustainable mining practices in its copper industry. Key initiatives and areas of focus include:

- Peru has implemented environmental regulations to mitigate the environmental impact of mining activities. These regulations cover issues such as water management, tailings management, and reclamation.

- Sustainable mining practices involve engaging with local communities and addressing their concerns. Community consultation and development programs are important aspects of responsible mining.

- Peru's copper mining industry faces challenges related to water scarcity. Sustainable water management practices are essential to ensure the availability of water resources for both mining operations and local communities.

- Similar to Chile, Peru has been working to improve energy efficiency in mining operations by adopting cleaner technologies and renewable energy sources.

China is a significant producer of copper, with various mines and smelting facilities across the country. The copper industry plays a crucial role in China's economic development and industrial growth. Copper mining and processing can have significant environmental impacts, including air and water pollution, habitat destruction, and soil contamination.

In China, addressing these environmental challenges has become a priority for the government and industry.

The Chinese government has implemented stringent environmental regulations and standards to mitigate the environmental impact of mining and processing activities.

These regulations cover areas such as emissions control, water management, and land reclamation. China has been investing in energy-efficient technologies and cleaner production methods in its copper industry.

These efforts aim to reduce energy consumption, emissions, and the overall environmental footprint of copper mining and processing. Efforts have been made to ensure responsible sourcing and ethical practices in the global copper supply chain.

China has been actively involved in global sustainability initiatives, including the United Nations Sustainable Development Goals (SDGs).

Responsible consumption and production, as outlined in SDG 12, are relevant to China's efforts to promote sustainable practices in its copper industry.

Sustainable mining is a holistic approach that recognizes the interconnectedness of environmental, social, and economic factors. It is a response to the growing global demand for natural resources, acknowledging that responsible resource extraction is critical for meeting these demands while safeguarding our planet's health and the well-being of local communities.

Certification programs and industry standards, such as the Responsible Mining Initiative and the International Council on Mining and Metals (ICMM) Principles, offer guidance to companies as they navigate the complex landscape of sustainable mining.

In the pursuit of sustainable mining, we can forge a path toward a future where the extraction of essential resources coexists harmoniously with the preservation of ecosystems, the enrichment of communities, and the betterment of all of society.

By embracing this vision, we can ensure that mining remains a vital contributor to human progress while respecting the limits of our planet.

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STUDY OF THE STABILITY OF THE WORKING BENCH OF QUARTZ SANDS

The current state of open-pit mining for construction minerals is characterized by the complex geological and hydrogeological conditions of their development and the intensification and concentration of mining operations. These features affect the stability of the slopes of the pits and sides of the quarries, which in turn determine the efficiency and completeness of the deposit development and the enterprise's technical and economic performance. Therefore, one of the main tasks of mining is to determine the optimal slope parameters to ensure their long-term stability with minimal mining operations. Excessive slope angles inevitably lead to the development of landslide phenomena that cause significant material damage to mining enterprises. In particular, mineral reserves prepared for excavation are exposed to landslides, and safe working conditions are compromised. Low slope angles cause a sharp increase in the volume of stripping operations and lead to the loss of minerals in the pit sides.

To quantify the stability of the slopes of the quarries, the concept of stability coefficient is used [1]. Therefore, one of the main tasks of the study is to calculate the slope stability coefficient.

The use of graphical constructions in calculations, the use of graphs and diagrams is quite convenient, simple, and meets engineering requirements. However, such calculations are limited in accuracy and multivariability and do not allow for more complex calculations for special conditions of slope stability [2]. The development of information technology has led to the development of several application packages for calculating slope stability by the methods of limit equilibrium (SCAD Soft "Slope", Rocscience Slide, Slope, GeoStab 5, etc.) and numerical methods that eliminate these shortcomings [3, 4].

An analysis of research on the stability of natural and artificial slopes shows that today there are a significant number of models, methods, criteria for rock strength, and ways to calculate the stability of a rock mass.

However, all the obtained results of calculations are reduced to establishing the shape and location of the sliding surface and determining the stability coefficient of the rock mass.

Given this, the research aims to determine the degree of stability of the quartz sand ledge at the Sykhivske deposit quarry using graphical constructions and in the Rocscience Slide software package in 2D based on the limit equilibrium method.

The mineral resource is fine-grained quartz sands, light grey, yellow-grey, loose, and slightly compacted.

The physical and mechanical characteristics of quartz sands of the Sykhivske deposit were determined based on laboratory and field studies and are as follows: bulk density - γ=1,66 t/m^3; coefficient of loosening - K_r=1,32; natural humidity of sands - W=2,83%; cohesion of sands in the rock mass – C=2 kPa; angle of internal friction – φ=33°; porosity coefficient – e=0,65.

According to the detailed design of the deposit development, the height of the working ledge should be H=20 m, and the slope angle should be α=30°.

However, in some cases, due to several objective reasons, the technological parameters at the quarry may not be met. In particular, due to the failure of working equipment and the high intensity of work, the slope angle of the working ledge can be up to 50° for some time.

This, accordingly, violates mining technololaborour safety and can cause landslides, cave-ins, and landslides [5].

The stability of the quartz sand ledge at α=50° was calculated in Slide 6 using the limit equilibrium method with the Mohr-Coulomb strength criterion [6].

Bishop, Janbu, and Spencer methods were used for the analysis

For the simplified Bishop analysis method, we have the global minimum sliding surface and stability factor contours in the central sliding grid with the minimum stability factor of all analyzed surfaces (Fig. 1*a*); the surface of the minimum stability factor (Fig. 1*b*); all sliding surfaces (Fig. 1*c*); sliding surfaces with stability factor values from 0,5 to 1,3 (normative) (Fig. 1 *d*).

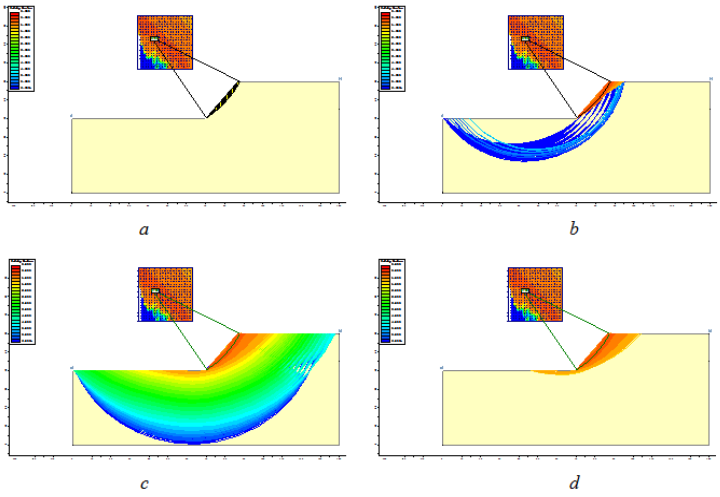

Fig. 1. Results of calculating the stability of the ledge by the Bishop's method: *a* - global minimum sliding surface and contours of the stability factor in the central sliding grid; *b* - surface of the minimum stability factor; *c* - all sliding surfaces; *d* - sliding surfaces with K_{st} from 0,5 to 1,3

For each analysis method, we obtained: the global minimum sliding surface and the contours of the minimum stability factor; the surface of the minimum stability factor; all possible sliding surfaces; and sliding surfaces with K_{st}, from 0,5 to 1,3. Analysis of the obtained indicators of slope stability shows that the Bishop and Spencer methods are almost identical. Thus, the stability coefficient of the ledge for Bishop is K_{st}=0,709, and for Spencer - K_{st}=0,703; the radii of the circular-cylindrical global sliding surface are the same and amount to R=52,145 m; the total displacement area at the global minimum for these methods is also the same S=40,649 m^2. The Janbu analysis method differs significantly in terms of K_{st}=0,677, R=38,54 m, S=48,643 m^2.

The sliding surface areas for all values of the minimum stability factor for these methods differ within 7,83 m.

The Janbu analysis method requires safer conditions, where the width of the hazard prism on the ledge surface should be 18,28 m. This is about 1 m more than the other methods. So, in general, the Janbu analysis method differs from Bishop and Spencer by 4-6 % in terms of the above stability indicators.

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RESEARCH OF THE INFLUENCE OF ROCK MASS FRACTURE ON ITS STRENGTH

The rock massif has its own structure, in particular, it contains natural and artificial cracks with varying degrees of opening and different materials filling them, varying degrees of water content, etc. The structure of the rock massif has its own structure. Consequently, there is always a spatial heterogeneity of the rock massif structure, which enhances the differences between its strength characteristics and those of its constituent rocks. To assess the magnitude of this difference, introduced the concept of the coefficient of structural weakening of the massif (CSW) [1, 2].

Usually, the formula for determining the coefficient of structural weakening is represented by the ratio of the uniaxial compressive strength of rocks in the massif to the uniaxial strength of the rock sample, established by the results of laboratory tests [1, 2]. However, the CSW can also be represented by the ratio of the tensile strength of rocks in a rock massif to the tensile strength of a laboratory sample.

Thus, in essence, the coefficient of structural weakening characterizes the associated level of ultimate stresses and stress state parameters of a rock massif depending on the rocks that compose it.

The overwhelming majority of formulas for determining the CSW use the degree of fracturing of the rock mass as the main indicator. And only a small group of studies additionally take into account one or more of the above-mentioned factors, in particular, the angle of dip of the main natural cracks, the minimum size of the rock structural block in the massif, etc. [3].

In foreign studies there is no term "structural weakening coefficient", but scientific research in the direction of studying and establishing the real strength properties of the rock massif is carried at a high scientific level. In particular, in [4] a rock mass state indicator RMR (Rock Mass Rating) is proposed, and in [5] a rock quality indicator RQD (Rock Quality Designation) is proposed, which in essence are analogs of CSW. Also, to assess the state of a rock massif, researchers in [6] suggest using the rock mass index RMi (Rock Mass index), which was developed to characterize the strength of rocks. The criterion of transition from the strength of a rock sample to the strength of a rock massif according to the method of Hoek-Brown [7] and some others are also known.

In the article [8] it was proposed to divide all scientific studies on determining the CSW of a rock massif and their foreign analogs into three groups. The first group includes data from tables and graphs on the determination of CSW depending on the parameters of rock massif fracturing. The second group of studies is proposed to be formed from publications that provide analytical calculation formulas for determining the CSW based only on the fracture modulus of the rock massif.

The third group includes studies that propose to determine CSW by analytical expressions that take into account, in addition to fracturing, other factors of influence on the strength of the massif.

The first group includes, first of all, normative documentation and reference books, in which CSW is determined by the average distance between cracks in rocky rocks based on the data of engineering-geological surveys. Among the analytical formulas for determining the numerical value of CSW, depending on the degree of massive cracking, which are included in the second group of studies, the most famous in Ukraine are the formulas of Sakurai, Shashenko O.M. and other well-known scientists.

Outside Ukraine, the state of disturbance of rock massifs is assessed by other indicators. In many cases they are similar to the structural weakening coefficient. In particular, in the U.S., the methodology for assessing the fracturing of a rock massif by the rock quality index RQD (Rock Quality Designation).

The classification of rock massif by RMR (Rock Mass Rating) is also known. The rock massif is also divided into five classes, as is the classification of rocks by the degree of fracturing in Ukraine. This suggests that the RMR values have a similarity with CSW.

It should be noted that there are some studies that indicate the inaccuracy of determining K_s only on the basis of the fracture index and additional factors (the third group of scientific studies) should also be taken into account [8]. These include the orientation of cracks in the space of the massif, the degree of crack opening, the material of filling the fracture space, cohesion at the contacts of individual pieces of rock, the scale effect (the size of the massif under study), the water content of the massif, etc. Indeed, the results of the studies of scientists from the third group allow us to improve the accuracy and reality of assessing the condition of the disturbed mountain range, but this greatly complicates the research itself and significantly increases its duration.

So, consideration of various methods of establishing CSW and indicators of assessing the state of disturbed rock massif shows that their essence both in Ukraine and abroad is the same. In order to summarize the results of the presented methods of assessment, the graphs of changes in CSW and indicators of assessment of the state of disturbance of the massif RQD and RMR depending on the fracture modulus were combined on one graph. RQD and RMR are presented in relative units.

For all the analyzed graphical dependences of CSW, RQD and RMR on fracture modulus, an approximation (trend) curve was constructed (Fig. 1) and the value of approximation reliability R^2 was established.

The value of reliability of approximation is as follows R^2=0,8975.

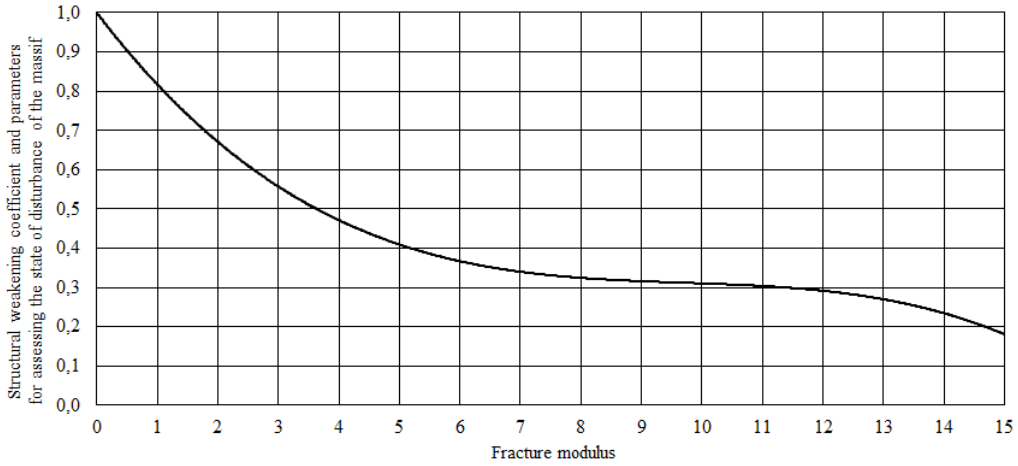

Fig. 1. Graph of approximation of values of the structural weakening coefficient and indicators of assessment of the state of disturbance of the rock massif depending on the fracture modulus

So, it is proposed, based on the results of the approximation it is proposed to introduce a generalized coefficient of reduction of strength of rock massif instead of the coefficient of structural weakening Ks, the indicator of rock quality RQD and the indicator of the state of disturbance of rock massif RMR.

At the same time, it should be taken into account that the calculation formula for its determination may change over time due to addition of new strength indicators.

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WET HIGH GRADIENT MAGNETIC SEPARATION OF KAOLIN CLAY

Abstract. Whiteness is the main parameter of kaolin process performance. The higher is the whiteness, the higher will be the purity and the value of kaolin clay. Kaolin clay is a combination of hydrated aluminosilicates, the main mineral component of which is kaolinite. It also contains impurities, which often reduce the whiteness of natural kaolin. Among them, iron-containing minerals are often the main substance that affects the whiteness of kaolin. Studies have shown the presence of a certain amount of particles of the iron containing minerals in provided kaolin sample. Wet high intensity magnetic separation was applied to remove magnetic grains from the natural kaolin clay sample. According to the XRF results, no iron minerals were detected in the purified kaolin (non-magnetic product), i.e. its content become less than 0,05%. The total content of magnetite in the magnetic product amounted 8%.

Purpose of work: to perform additional enrichment in order to extract impurities from kaolin raw material in a form of dark iron containing minerals, which strongly affects the whiteness of kaolin clay.

Research object: natural kaolin raw material, light brown, particle size less than 50 microns.

Keywords: kaolin clay, whiteness, magnetic separation, high gradient magnetic field, kaolinite, calcite, impurities.

Magnetic separation of kaolin was carried out in order to extract magnetic impurities. Studies of the HGMS process for kaolin were carried out on a laboratory high-gradient magnetic separator [2,3].

The separator is a system of permanent magnets with a magnetic core and a cassette with a magnetic medium [1]. NdFeB permanent magnets with N52 magnetization were used. The magnetic field is closed by a magnetic system. In a gap between magnets measuring 10 mm, the magnetic induction is 0,8 T.

A non-magnetic cassette filled with magnetically conductive stainless steel wool is placed in this gap. This separator is a periodic device. A given amount of kaolin suspension with a solid content of 70 g/l was poured through the magnetic medium.

After filling the cassette with magnetic iron-containing particles, the supply of the suspension was stopped, the cassette was removed from the separator and washed, so magnetic particles (impurities) were removed from the magnetic wool.

Then the separation process was repeated.

According to the XRF results, no iron minerals were detected in the purified kaolin (non-magnetic product), i.e. its content become less than 0,05% (Fig. 4).

The total content of iron containing minerals in the magnetic product amounted 8% (Fig. 3).

The non-magnetic separation product changed color to much whiter, which was confirmed by the results of observing magnetic separation products under a microscope with 200x magnification (Fig. 1,2). Whiteness was not estimated.

Fig. 1. Magnetic product *x200*

Fig. 2. Non-magnetic product *x200*Results of X-ray phase analysis of enriched kaolin samples. XRF analysis was performed on a DRON-2 X-ray diffractometer in monochromatized Co-Kα radiation (l=1,7902A)

Identification of compounds (phases) was carried out manually by comparing interplanar distances (*d*, A) and relative intensities (I_o-I/I_0) of the experimental curve with data from the PCPDFWIN electronic file cabinet.

Fig. 3 shows, that the sample contains amorphous-crystalline phases in the following quantities: quartz - <2%; iron minerals - 8%; calcite - 23%; kaolinite - 65%; unidentified phase - 2%.

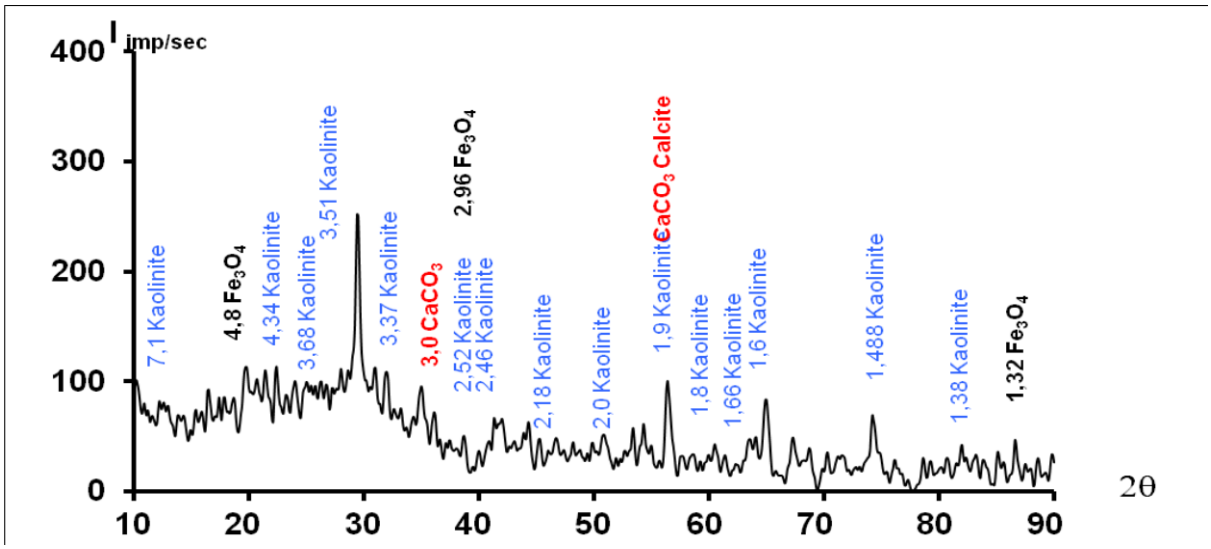

Fig. 3. Sample Kaolin B, magnetic product, Co-Kα radiation

Fig. 4 shows, that the sample contains crystalline phases in the following quantities: kaolinite - >98%; unidentified phase - 2%.

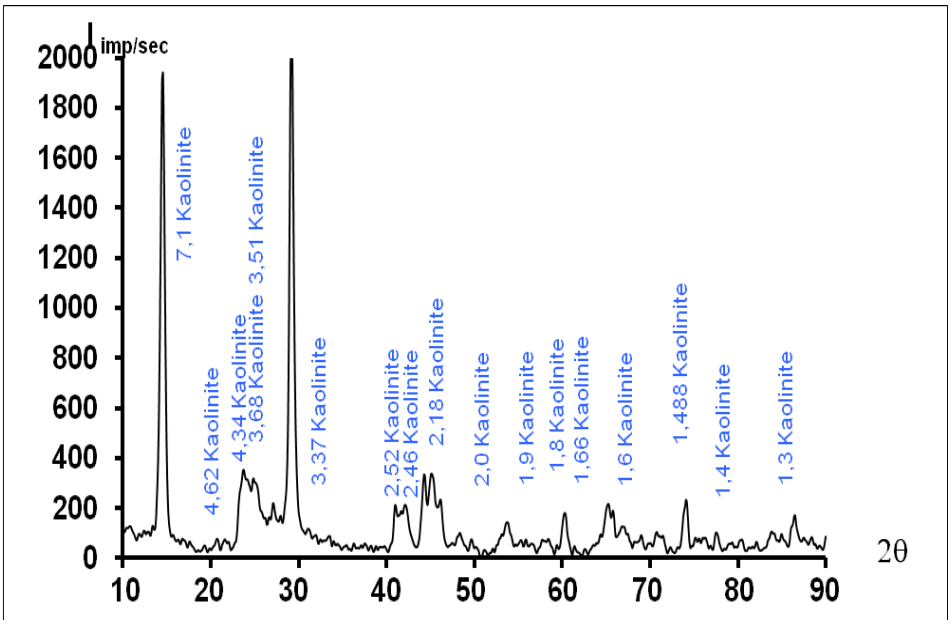

Fig. 4. Sample Kaolin B, non-magnetic product, Co-Kα radiation

Conclusion

In the provided kaolin sample there were found magnetic particles in a form of dark iron containing minerals, which strongly affects the whiteness of kaolin clay.

Wet high intensity magnetic separation was performed to remove magnetic grains from the natural kaolin clay sample.

The non-magnetic separation product changed color to much whiter (Fig. 2), whiteness was not estimated.

According to the XRF results, no iron minerals were detected in the purified kaolin (non-magnetic product), i.e. its content become less than 0,05%.

The total content of iron minerals in the magnetic product amounted 8%.

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DEVELOPMENT TRENDS OF THE MINING INDUSTRY IN VIETNAM

The world is currently moving into the era of Industry 4.0, this is a term that refers to high-tech scientific developments such as the internet of things, artificial intelligence, virtual reality, social networks, cloud computing, mobile, big data analysis, ... to transform the entire real world into a digital world, computerizing the production process without human participation.

In that context, the mining industry still plays an important role in providing raw materials to produce advanced materials, especially rare and high-value metals serving Industry 4,0.

The mining industry which encompasses exploitation and mineral processing (including mineral enrichment) is an important industry, producing raw materials for other industries and playing a major role in economic development, society, especially for developing countries like Vietnam.

The mining industry development is essential for the process of industrialization and modernization of the country according to the goals set by the Party and Government for the present and upcoming years.

Therefore, putting forward orientations and solutions appropriate to minimize negative impacts on the environment is the current, medium and long-term trend of the mining industry in general and of Vietnam's mineral processing industry in particular.

This article presents the global trajectory of sustainable the mining industry advancement and proposes potential measures for Vietnam's mineral processing industry to contribute significantly to the sustainable development trend of the mining industry.

Keywords: Mining industry, exploitation, mineral processing, development trend

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RESEARCH THE MOVEMENT OF LORRY CONVOY ON CURVED TRAJECTORY BY BRAKING WHEELS ON ONE AXLE

It is known that container transportations - one of the most convenient and economic types of cargo delivery, carried out as on the local and international organization of transportations. Considering that freight transportation of containers differs in the high level of safety and simplicity of customs registration, they are widespread around the world and volumes of their transportations grow from year to year.

The current state of development of the rolling stock of the motor transport for transportations of containers is characterized by variety of types and types of cars, trailers and semi-trailers, however more rational are transportations of containers by multiple-purpose semi-trailers. So, Fliegl exhausts wide scale of container carriers among which is multiple-purpose for transportation of all types of containers including tanks containers, dimension from 20 to 45 feet and HQ containers.

For multiple-purpose container carriers when transporting 45-foot containers it is necessary to prolong the lorry convoy, and it worsens entry it into turning movement.

Increase in the overall traffic lane creates danger to counter transport, complicates movement in city conditions and reduces the average speed of the movement of all transport stream.

Improvement of a fitting of the lorry convoy in turning movement is possible at the expense of the steered (self-established) axels (wheels) of the semi-trailer or steering of the semi-trailer by braking of wheels of one axle.

For determination of turning radius of the semi-trailer when steering by braking of wheels of one board of the cart it is necessary to define normal reactions of a seating to wheels of one board of the cart and coefficients of resistance of withdrawal of internal and external wheels which are functions, both normal loading, and the braking torque operating on a wheel or a board of the cart.

For definition of redistribution of vertical loads of wheels of the cart of the semi-trailer we will consider the movement of the lorry convoy on turning movement [1].

As a result, due to change of reactions on boards of the cart of the semi-trailer it is necessary to consider change of coefficient of resistance of withdrawal of wheels of its axles from a normal

wheel load. At the same time we will use D. A. Antonov's dependence for definition of side reaction on wheels of axles of the cart of the semi-trailer [2].

In case of braking of wheels of one axle, its situation we will define at the movement of the lorry convoy on the unsteady turning movement.

The movement of the road train which is considered, on curvilinear (in the plan) of a trajectory treats plane-parallel.

It allows to use at research of the unsteady turning movement of such lorry convoy the theorem of addition of rotations around parallel axles [3].

As a result of calculations it is established that the movement of the lorry convoy with the uncontrollable semi-trailer on circular trajectories is possible only under a condition if the radius of a curve is more than base of the semi-trailer.

At the same time the overall traffic lane admissible value which is equal to 7,3 m is provided with lorry convoy with uncontrollable the cart only in that case when length of the road train doesn't exceed 16,8 m (at the same time the maximum base of the semi-trailer doesn't exceed 7,0 m).

If the base of the semi-trailer exceeds the specified size, then the cart of the semi-trailer has to be steered, as at the expense of the self-established axle, and braking of wheels of one side or wheels of one board.

It is established that the trajectory of the movement of the steered semi-trailer by braking of wheels of one board on the unsteady turning movement always consists of two sites, various on a curvature sign therefore for correction of a trajectory of the cart it is necessary to change also wheels of a axle, which need to be slowed down.

It is established that on a semi-trailer entrance to turning movement and an exit from it, on an entrance transitional trajectory the direction of additional side force on a front steered axle always coincides with the direction of side force on the semi-trailer cart and therefore braking of wheels of a front axle least changes a trajectory of the movement of the cart.

Therefore braking of wheels of one party of a rear axle of the cart of the semi-trailer is expedient.

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PISTON LIQUID SLOSHING IN A VERTICAL VIBRATING CONVEYOR

Vibration machines for processing bulk materials in liquids can be widely applied in various industries. Piston liquid sloshing and elastic vibrations of liquid column are potential during the operation of vibration machines to process bulk materials in fluids.

Let us analyze the impact of piston liquid sloshing on the liquid pressure amount in the vibrating conveyor trays and working body vibrations as well.

To do this, we will accept the following assumptions: liquid-containing cavity remains absolutely rigid; cavity wall contact with the liquid is constant; wave processes at the liquid column ends can be neglected; a screw cavity section is accepted as rectilinear and inclined to the horizon at an angle α (where α is the horizon angle of the vibrating conveyor tray). We obtain the differential equation for liquid column oscillations by applying Bernoulli's equation, based on the calculation scheme in fig. 1.

$$z_2 + \frac{p_2}{\rho g} + \frac{V_2^2}{2g} = z_1 + \frac{p_1}{\rho g} + \frac{V_1^2}{2g} + \frac{1}{g}\int_l \frac{dV_i}{dt} dl_i + h_w, \quad (1)$$

where z_l,z_2 - position pressures; $p_1/\rho g$, $p_2/\rho g$ - piezometric pressures; h_w - pressure loss due to resistance caused by fluid movement.

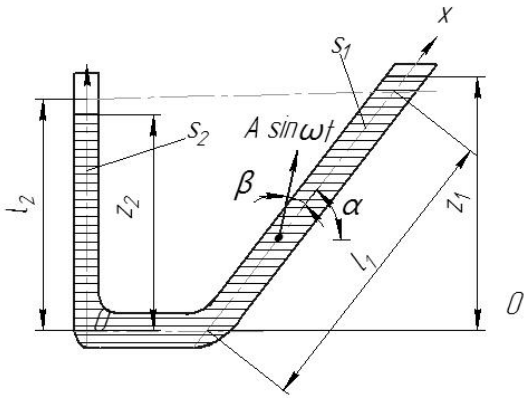

Fig. 1. Calculation scheme for studying piston liquid sloshing

The penultimate term on the right side of equation (1) determines the inertial pressure of the liquid column. By neglecting the horizontal section which size is very small compared to the other two ones, the expression for the inertial pressure of the liquid column can be written as

$$\frac{1}{g}\int_l \frac{dV_i}{dt} dl_i = \frac{1}{g}\frac{\partial V_1}{\partial t}\left(l_1 + \kappa_f l_2\right) = \frac{1}{g}\ddot{x}_1\left(l_1 + \kappa_f l_2\right), \quad (2)$$

where x_1 - is the movement of the liquid column in the inclined section.

Pressure loss due to the resistance caused by the fluid movement h_w is defined as

$$h_w = h_{w1} + h_{w2}, \quad (3)$$

where h_{w1} и h_{w2} - are the pressure losses in the first and second sections, correspondingly.

To simplify the solution of the differential equation of fluid motion, pressure losses on curvatures were replaced by equivalent losses that are proportional to speed.

As a result, we have found that the piston liquid sloshing amplitude for considered vibration machines is about 2...3 orders lower than the vibration amplitude of a vibrating conveyor tray. Thus, piston liquid sloshing is almost non-existent and has no impacts on the liquid pressure amount in the vibrating conveyor trays and working body vibrations as well.

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FINISHING AND CLEANING PROCESSING OF DETAILS IN THE VIBRATION CENTER INSTALLATION

The rate of development of modern technologies of the machine-building industry and repair production constantly requires the search for new methods of finishing and cleaning processing (FCP), which have high productivity and wide technological possibilities. One of the effective ways to solve this problem is to carry out FCP of machine parts with granular media in technological systems of the centrifugal-vibration type, the working chamber of which performs complex movements. The advantages of such technological systems lie in the expansion of the range of changes in the resulting vectors of movement of ingredients (parts and granules) of working environments, increasing the intensity of their mixing and reorientation. This determines the perspective of their application to increase the productivity of FCP.

At the same time, there are still many unsolved issues that prevent the practical application of FCP in granular working environments. In particular, in the works devoted to the research of such processing of parts, there is no unified approach to the description of the kinetics of the movement of granular working media and their contact interaction with the processed part, the relationship between the quality and intensity of the process and the design parameters of the installations is insufficiently substantiated theoretically, and there are no corresponding analytical dependencies. All this in a complex determines the relevance of research in the field of vibration technologies of FCP.

The purpose of the work is to establish the regularities of finishing and cleaning processing of various profile parts in a vibro-centrifugal installation.

Presenting main material

One of the effective solutions for performing FCP parts is the use of technological systems with a horizontal axis of rotation of the working chamber or its elements. The working unit of such a technological system must implement the process of volumetric FCP along the entire profile of the part and allow the unhindered movement of the part through the working area.

Requirements are placed on parts that are processed on vibration units, in particular:

- the thickness of the base of the mold along the line of separation of the casting mold on the parts obtained by pressure casting should not exceed 0,5 mm;

- the maximum height of burrs along the contour of parts obtained by sheet stamping should not exceed 30% of the thickness of the sheet, and the thickness of the base of the burrs should not exceed 1,5 mm;

- blind holes and grooves can be treated only when the size of the granules of the working media does not exceed 0,3 of the diameter of the hole or the width of the groove. At the same time, the depth of holes with a diameter of up to 10 mm should not be greater than the diameter of the holes, with a diameter of 10-15 mm - no more than two diameters. The depth of a groove with a width of up to 10 mm should be greater than its width, a groove of 10-50 mm should be slightly more than twice its width.

One of the constructive solutions of the technological system for FCP of various profile parts [1] is the installation, which allows to ensure a high-energy process of processing parts in the working zone created by a cylindrical insert and two half-drums freely installed on the insert. The half-drums rotate in the insert, and their drives ensure their counter-rotation. And the installation of a cylindrical insert in the cardan suspension ensures its movement in the form of a cone.

The movement of the mass of the working medium in the installation can be divided into two stages: movement in direct contact with the walls of the installation and movement away from these surfaces.

Analysis of the kinematics of the movement of the particles of the processing medium adjacent to the walls of the installation allows obtaining the dependence of the absolute speed and acceleration of the particles of the processing medium on the geometric parameters of the insert and its angle of inclination to the axis of rotation. These are the initial conditions for determining the dynamic characteristics of the environment, which allows us to consider the conditions for the detachment of their particles when the elements of the loading mass go into the sliding mode. When rolling, the upper layers of the load mass rotate around their axes, pulling in the adjacent layers of particles of the load mass, and as a result, they roll relative to each other. In addition, when an avalanche rolls down the uneven surface of the lower layers, microshocks and sliding of particles of loading masses occur.

Thus, the parts are processed in the process of mutual friction, scratching and micro-impacts of the ingredients of the working environment. The intensity of these processes depends on the size of the working area, the mass of the ingredients of the granulated medium, the geometry of the working volume and its filling factor, the speed of rotation of the semi-drums and other factors.

The change in the intensity of the impact on the processed part is due to the change in the number of sliding layers of the medium in the process of transferring the energy of the part from the walls of the insert and half-drums. Changing the angle of inclination of the insert relative to the axis of its suspension provides additional longitudinal movement of the mass of the processing medium and changes the general nature of its movement. The mass of the working medium can move between half-drums (from the periphery to the center and back), making a circulation movement and changing the density of the medium in different zones of the working volume. Therefore, the ingredients of the working medium carry out a complex movement consisting of translational movement together with the elementary layer and oscillations with a small amplitude.

As it follows from the proposed model of the movement of ingredients of the loading mass in the working zone, the layers of the working medium in the area of the cardan suspension of the insert have a low speed of movement. Therefore, the surfaces of the parts falling into this area are less affected by the granules and, as a result, are less efficiently processed. In the conditions of real processing, the instantaneous centers of movement of the ingredients of the working environment do not have a clearly fixed position, changing it chaotically. Therefore, for practical calculations, the thickness of the sliding layer with a sufficient degree of probability can be taken at the level of half the height of the loading mass in the working area of the installation.

It follows from the above that the main characteristics that determine the dynamic state of the working environment and, as a result, the technological effect of processing, are the pressure of the environment and the speed of its movement. These two factors collectively determine the density of the energy impact of the flow of the granular medium on the surface of the part, and the efficiency of processing.

Conclusions

1. Based on the analysis of the movement of particles of the working medium in the vibrocentrifugal installation, it was established that the main geometric and kinematic characteristics that determine the technological effect of processing are the angle of oscillation of the cylindrical insert relative to the axis of rotation and the frequency of rotation of the half-drums.

2. Providing the part with additional counter-rotation in relation to the direction of movement of the flow of ingredients of the working medium, additionally intensifies the surface treatment process by increasing the time of contact interaction of the part and abrasive granules.

3. The greatest technological effect of the FCP in the installation is achieved under the conditions of its loading within 60-70% of the volume of the working area and the speed of rotation of the semi-drums no more than 50-60 rpm.

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LOGISTICS RISKS OF TRUCK TRANSPORTATION

Truck transport plays a major role in moving a large quantity of products from the place of production to the place of consumption. The road transport has an important role in supporting the functioning of many branches of production especially in the conditions of martial law. Due to mobility and the possibility of door-to-door goods delivery, it can be said that it occupies a priority place in delivery process.

The transport process of truck transportation (hereinafter - TT) can be characterized as a probabilistic change of random events over time. Depending on the conditions of transportation, namely intensity of traffic, climatic conditions of the external environment and the psychophysiological well-being of the driver are directly depend the safety of the transportation process. That’s why the safety transportation process provides it’s the main goal - the delivery of the appropriate type of cargo, without losses, to the destination at the specified time with minimal losses. The balance, efficiency and safety of the transport process depend on many factors. Anticipation of possible incidents and dangerous events during cargo transportation means saving of the life of the driver and other participants in the transportation process, saving the cargo, saving financial costs incurred by the trucking company (hereinafter referred to as TC).

On the basis of the issue state analysis and the provisions of the system analysis, was defined a system in the area of logistical risks study that arise when a driving a truck at transporting oversized and heavy objects, i.e. it is a formed "driver-truck-road-environment" system. In this system characteristics of each element are a source of logistics risk formation. The main incident or dangerous event during the execution of oversized and heavy objects TT is the risk of a traffic accident. Ac-

cording to information [1-3], the main causes of road accidents in the "driver-truck-road-environment" system include:

- unprofessional selection of drivers;
- difficult working conditions at cargo transportation;
- unsatisfactory psychophysiological well-being and health conditions;
- high intensity of movement;
- unsatisfactory condition of road infrastructure;
- non-compliance of the truck with the transportation conditions;
- unsatisfactory technical truck condition;
- lack of a proper maintenance and repair system, etc.

It should be noted that the main element in the "driver-truck-road-environment" system is the driver. The reliability of the TT process depends on drivers' professional experience and skills, on his physical health and psychophysiological conditions. The driver must feel satisfaction from the performed work. This is a manifestation of the fact that TC pays decent wages and has social security for workers. There are additional payments for hard work and special conditions of professional activity. The TC management allows drivers to improve their own skills, is concerned about creating a friendly atmosphere in relations between workers at the TC, is concerned about their recovery, ensures workers' access to modern medical services, etc. The driver must be satisfied by the ergonomics of the workplace. This is achieved by the driver's confidence in the technical condition of the truck, the quality of the pre-flight technical inspection, the presence of effective safety elements and systems in the design, the presence of an effective climate control system in the cabin in conditions of cold or warm seasons, lighting systems and equipments - this is important for the truck driving in the dark, etc. Therefore, in order to improve the existing methods of the logistical risks studying of the "driver-truck-road-environment" system, it is necessary to take into account the above-listed influencing factors.

Taking these factors into account will allow obtaining a more realistic research result, on the basis of which it will be possible to develop effective management solutions aimed at minimization or elimination of hazard factors. Using the logistics risk management tool will allow specialists involved in the TT planning and organization at all stages of the transport process to use an effective model of logistics risk management, which is aimed at increasing its safety.

To assess the logistical risks during the TT of various cargoes the most common are the "Hazard and Operability Study" method (hereinafter - "HAZOP") and the "Failure Mode and Effects Analysis" method (hereinafter - "FMEA). These methods are well combined with each other and allow detailing each stage of the TT transport process to identify hazards and the overall system performance, which is carried out by a specially selected group of experts. In addition, their use for

assessing the logistical risks degree in the TT implementation is recommended by a number of regulatory requirements [4-6].

The first step is to identify the hazards and performance of the TT system. To determine an incident (logistics risks) we will use several key words of the "HAZOP" method [7].

The second step is devoted to the quantitative assessment of logistical risks that arise as a result of changes in the psychophysiological well-being of the driver during the TT execution. To do this, we will use the algorithm of the "FMEA" method, which allows, based on the application of organizational, logical, mathematical and statistical procedures, to calculate the priority rank of logistical risks of the occurrence of a dangerous situation based on three indicators: the severity of consequences (*S*), the probability of failure/incident (*O*) and the possibility detection of a defect that is associated with a dangerous action or no action (*D*). The last indicator is related to determining the influence of the psychosocial conditions of the driver on the occurrence of human error - dangerous action or no action during the execution of the TT. According to the rank of logistic risks provides the selection and justification of rational solutions, which are aimed at increasing the safety of TT through the generalization of the obtained estimates. The product of the specified components *S*, *O* and *D* allows determining the value of RPN according to the formula [8]

$$RPN=S\times O\times D$$

A scale from 1 to 10 is used to determine indicators of the severity of consequences (*S*), the probability of failure/incident (*O*) and the possibility of detecting a dangerous condition (*D*), where 1 is the smallest value of the indicator, and 10 is the largest. The evaluation of logistics risks, which is obtained according to the algorithm of the "FMEA" method, continues until the full identification of the value of *RPN*, which indicates the highest values of the value of logistics risks. The most influential factors are those in which the RPN value exceeds 150 points [7].

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COMPENSATION OF DYNAMIC LOADS OF CHAIN TRACTION MECHANISMS BY MEANS OF ELECTRIC DRIVE

Abstract

The reasons for the occurrence of periodic dynamic loads in the mechanical part of the scraper conveyor are analysed and a method of their compensation by means of an electric drive is proposed, which will contribute to the reduction of metal capacity and increase the reliability of the scraper-chain drive mechanism.

Key words: scraper conveyor, scraper-chain mechanism, adjustable AC drive, original control method.

Introduction

One of the ways to increase the productivity of mine cleaning works is more intensive loading of mining lava. This is usually achieved by increasing the capacity of the mining combine, which is traditionally operated in conjunction with means of transportation and loading and unloading of useful raw materials. It is obvious that due to the increase in the productivity of the main technological equipment, the scraper conveyors of the mining complex work in a more intense mode.

It is possible to provide the increased capacity of the combiner in the case of realizing the speed of the chain movement, which approaches the limited limits of 0,3 1,6 m/s.

Such circumstances contribute to reducing the resource of the drive mechanism and force manufacturers to introduce chains with a higher metal capacity and with the involvement of alloyed metal with a tenfold safety margin [1, 2]. Under such conditions, the improvement of the traction mechanism plays a very important role in ensuring the reliability of scraper conveyors.

The purpose of the paper is to analyse the mechanics of dynamic loads in the chain drive mechanism of conveyor scrapers and, based on this information, to justify and provide recommendations on the method of their electromechanical damping, which will ultimately avoid emergency situations and provide conditions for the construction of a more efficient drive system with lower capital costs.

The main part

From the study of conveyor kinematics, it was established that the source of dynamic overloads is the imperfect design of the drive unit (Fig. 1*a,b*).

For the circuit shown, the conveyor chain is driven by a star rotating by an unregulated drive with a constant angular velocity ω.

Despite this, the scrapers move unevenly because the chain links lie on a circle of variable radius (Fig. 2).

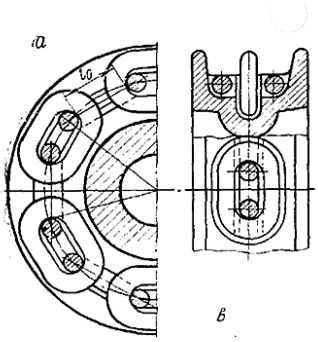

Fig. 1. Chain drive star:
a – side view; *b* – section

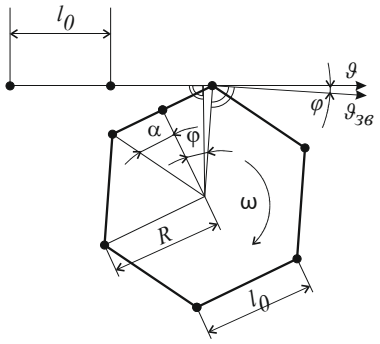

Fig. 2. Equivalent polyhedron

This circumstance causes chain speed fluctuations within the rotation of the star by the central angle 2α, which corresponds to one face of the star. Under such conditions, the linear speed of rotation of the star is equal to

$$\upsilon_{зв}=\omega R, \text{ (m/s)}$$

where R stands for radius of the star initial circle, m.

When turning the star by an angle φ (Fig. 2), which changes from α at the beginning to $+\alpha$ at the end of engagement with the star tooth, the speed of the chain movement is determined by the equation

$$\upsilon=\upsilon_{зв}cos\ \varphi = \omega R cos\ \varphi.$$

That is, the speed of the chain within one engagement period varies according to the sine wave, and the acceleration $a=dv/dt$ according to the cosine wave. At the same time, the maximum acceleration of the chain is equal to

$$a_{\max} = \omega^2 R \sin\alpha.$$

A separate problem that reduces the efficiency of the drive unit is the introduction of a turbo coupling to its composition, which protects the conveyor elements from overloads and ensures a smoother start-up and reduces the dynamics of the mechanism. When the conveyor chain jams or in case of excessive overloads, the turbo clutch automatically stops the transmission of torque from the electric motor to the gearbox and stops the conveyor.

The authors of the publication propose to solve the problem of emergency and excessive metal content of alloy steel by using a modern alternating current electric drive with control from a frequency converter. From the analysis of the operation of the mechanism, it was established that it should work with a constant tension of the chain with a force known in advance. That is, maintaining a constant effort on the drive traction mechanism of the scraper conveyor will ensure the protection of the electromechanical system from all the listed accidents. Thus, for this electromechanical system, it is necessary to use a control system with engine motor stabilization.

The scientific novelty of the paper consists in establishing the causes of accidents and in providing recommendations on the method of electromechanical damping of dynamic forces in the

scraper conveyor chain, which will avoid non-productive downtime and build an efficient drive system with lower capital costs and in the absence of a turbo coupling.

Conclusions

The development of recommendations for the improvement of the electric drive system with electromagnetic damping of shock loads will ensure a significant reduction in emergency situations, reduce downtime and, as a result, increase profits due to a greater number of finished products that are produced during production time.

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OPTIMIZATION OF STRATEGY PARAMETERS “IN CONDITION” MAINTENANCE WITH CONSTANT MONITORING FREQUENCY IN MECHANICAL ENGINEERING AND ROAD TRANSPORT

Complex technical objects in modern society are extremely important. First of all, we are talking about various radio-electronic complexes for military and special purposes, radar stations, automated control systems (air traffic, energy facilities, etc.). The level of reliability such facilities depends on the defense capability of state, economic security, lives of hundreds and thousands of people.

Such objects belong to the class of recoverable objects of long-term multiple use. They tend to be expensive and require significant maintenance costs. To ensure the required level of reliability during their operation, maintenance is usually carried out, the essence of which is timely preventive replacement of elements that are in a pre-failure state.

This paper discusses the modeling of maintenance process "on condition" with an adaptive change in the frequency of control.

A characteristic feature of complex technical objects for special purposes is the presence in their composition of a large number (tens, hundreds of thousands) of different types components that have different levels of reliability, different patterns of their wear and aging processes. This feature requires a more subtle approach to the organization and planning of maintenance during their operation.

Currently, there is a decrease in the number of scientific publications devoted to the operation of complex technical objects. One of the reasons for this, in our opinion, is a sharp increase in the level of integration and reliability of components. Thanks to this, developers of complex equipment have been able to solve the problems of ensuring the required level of reliability without significant maintenance costs (or no maintenance at all). However, for the same reason (high integration and reliability of components), it became possible to implement more and more complex equipment with new functions, which was impossible with the old element base. This again objectively leads to reliability problems and, therefore, the question of need for maintenance and the choice of optimal strategy for its implementation again becomes relevant.

Unfortunately, the currently known mathematical models and methods for calculating the optimal parameters of maintenance processes are not very suitable for application to real technical objects. The main disadvantage of these models is that they either do not take into account the complex structure of the object, or it is possible to take into account only some of the simplest structures [1,2]. In [2,3], a comparative analysis of the problems that arise when solving maintenance problems "by resource" and "by state" is carried out. An overview of the latest work in the field of maintenance and repair of complex systems at that time. In [3], a theoretical generalization of known mathematical models of MS processes was made. However, these models do not allow one to construct a methodology suitable for practical use on their basis.

The problem is that when developing such facilities, all issues related to maintainability and maintenance should be addressed already at the early stages of the design facility. If you do not provide in advance the necessary hardware and software for integrated monitoring of the technical condition (TC) of the object, do not develop and “embed” the maintenance technology into the object, then it will not be possible to realize in the future a possible gain in the reliability of object due to maintenance. Since all these issues must be resolved at the stage of creating an object (when the object does not yet exist), mathematical models of the maintenance process are needed, with the help of which it would be possible to calculate the possible gain in the level of reliability of object due to maintenance, to estimate the cost costs required for this. Then, based on such calculations, make a decision on the need for maintenance for this type of objects and, if such a decision is made, develop the structure of maintenance system, choose the most appropriate maintenance strategy, and determine its optimal parameters.

Conclusions. In this section, an ISM has been developed that is designed to predict the reliability indicators and the cost of operating a complex technical object, depending on the parameters of the chosen maintenance strategy. IMS implements algorithms for simulating maintenance processes for - MC with adaptively changing control frequency.

The regulated maintenance modeling mode was introduced in order to ensure the completeness of analysis possible maintenance strategies for the designed facility and to predict the possible gain in reliability and cost of operation facility through the application of MC strategies.

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VIRTUAL REALITY ILLUSTRATION OF DYNAMIC SYSTEM MECHANICS USING A SCREEN EXAMPLE

In recent years, VR technology has expanded beyond gaming to influence various industries, notably the industrial sector. VR facilitates realistic simulations for training new personnel without risks, and assists engineers in cost-effective prototyping, testing, and international collaboration through virtual meetings. Notably, companies like Ford utilize VR for prototype development and testing, while Volkswagen leverages it for employee training and customer demonstrations. Analyzing these applications, a scientific-technical problem arises: developing a universal data integration system between SolidWorks and Unity for simulating and testing 3D models, enabling intricate interactions and mechanism dynamics within a VR environment. This is explored using a technical object - a screen - as an example. To develop the project of virtual interaction with the screen we use the previously created computer model of the screen. The virtual model of the screen was created in SolidWorks software product.

Several recent updates to the SolidWorks software suite have added the addition of virtual reality (VR). In the context of SolidWorks VR, can be used to immerse yourself in your 3D models in a VR environment to better understand scale and proportion, as well as work together across the globe to discuss and demonstrate models in real time, effectively test designs without creating a physical prototype, and impressively present them to customers or stakeholders. Unfortunately, SolidWorks VR from SolidWorks currently lacks sophisticated viewer interaction with the object. For example, the designer cannot make changes to the model directly in virtual space while discuss-

ing the prototype. Also, there is no way to demonstrate in detail how the mechanism works by putting it in motion. In order to create deep interaction with the model, additional features such as Unity development environment and C# programming language are required.

It should be noted that there is no direct format of data transfer from SolidWorks to Unity. Additional software products were used to format 3D models created in SolidWorks for further work with them in Unity.

The main purpose of transferring the model to Unity was to create an application to demonstrate the principle of operation of the screen in virtual reality. Let us describe the simplest algorithm of creating the application.

After loading the rumble model into Unity, the first step in processing the model in Unity is to create the model collider. Colliders are used to detect collisions and interactions between objects in the scene, as well as to create physical effects, allowing you to implement mechanics such as collision, bounce, destruction and other physical effects. For the rumble we used a collider from standard forms - Box.

In order to recreate the operation of the screen, it is necessary to understand the nature of its motion. During operation, the screen makes oscillating movements, which are provided by a motor-vibrator mounted on the screen and the springs on which it rests. Thus, a C# script is created and attached to the screen to simulate sinusoidal motion.

```
using UnityEngine;
public class Oscillation : MonoBehaviour {
public float amplitude = 1f; // Vibration amplitude
public float frequency = 1f; // Oscillation frequency
public Vector3 direction = Vector3.up; // Oscillation direction
private Vector3 initialPosition;
void Start() {
initialPosition = transform.position;
}
void Update() {
// Calculate new position
float movement = Mathf.Sin(Time.time * frequency) * amplitude;
Vector3 newPosition = initialPosition + direction.normalised * movement;
// Update the position of the object
transform.position = newPosition;
} }
```

Fig. 1. Script code for modelling the oscillatory motion of the screen

How this script works:

1. Set the amplitude, frequency and direction of oscillation.

2. Memorise the initial position of the object at startup.

3. In each frame (Update) we calculate a new position based on a sine function. First calculate the offset using the sine of the current time (Time.time) multiplied by the frequency. Then multiply the result by the amplitude and normalised direction of the oscillation.

4. Update the object position with the new value.

5. Attach this script to the rumble, to create oscillations. The parameters amplitude, frequency and direction of the oscillations can now be controlled in the Unity inspector or directly in the code.

Vivo's virtual reality headset, which consists of a helmet, controllers and motion-sensor racks, was used to display the semi-improved results.

In conclusion, analysing the use of SolidWorks Virtual Reality to demonstrate the operation of a screening machine reveals the potential and limitations of this product. Whilst SolidWorks VR allows the visualisation of 3D models, it limits the ability to represent the operation of objects in virtual space. Additional software tools, such as the Unity development environment and the C# programming language, are required to realise more complex interactions and demonstrate the operation of the mechanisms, as shown in the example of the screen.

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CONCEPTUAL PRINCIPLES OF ENSURING TRANSPORT SAFETY OF CITIES

Ensuring transport safety of cities is a priority direction of the developed countries of the world. Every year, the level of threats, the number of vehicles and people who can use them increases, and therefore the task becomes very difficult.

According to the latest statistical data, 7 out of 10 terrorist acts occur at transport infrastructure facilities [1]. Transport, as one of the most important components of the economy of cities and regions, constantly attracts a huge number of people, which makes the development and implementation of various transport safety systems one of the priority tasks [2].

A complex system of measures that ensure safety in transport usually includes various tools. Developers of these tools are government bodies or relevant services of various transport companies. Such tools can be:

- measures of an organizational and administrative nature that contribute to the protection of objects and vehicles;
- engineering measures, which are expressed in specific architectural and planning solutions;
- technical measures for the development, implementation and application of means that ensure the protection of transport infrastructure objects in an autonomous mode;

- specially trained employees of state law enforcement agencies and private security services working in the field of transport safety.

The city's transport system is a human-machine system that must have a high level of operational reliability and traffic safety [3]. Ensuring safety in transport requires a comprehensive approach. In addition to constant updating of existing parts, it is necessary to add new subsystems.

Accelerating technological development brings the video surveillance system to the fore as part of transport safety. It is around it, as a rule, that the whole complex of tools is built, which provide protection against unauthorized intrusions and other actions that create danger.

A good tool for ensuring processes of safety in transport is the intellectualization of road and traffic flow management [4].

In general, it is customary to call an intelligent transport system (ITS) a complex of subsystems that make possible the efficient operation of transport using information, communication and management technologies built into vehicles or road infrastructure.

The main tasks that are solved by specialists who ensure the operation of «smart transport» are the collection, processing, integration and distribution of information.

Complexes of functional equipment included in intelligent transport systems collect data, regulate the traffic flow and convey the necessary information to each road user (Fig. 1).

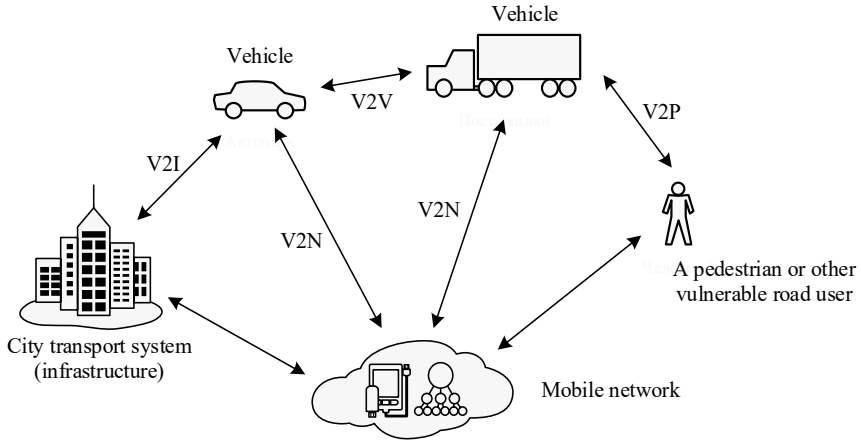

Fig. 1. Types of communications in ITS

The work of intelligent transport systems to ensure traffic safety includes the use of subsystems designed not only to record violations of traffic rules, but also to prevent traffic accidents.

Thanks to various devices, punishment for traffic violations that lead to dangerous situations on the roads has become almost inevitable, which has encouraged drivers and pedestrians to behave more responsibly on the roads.

To improve traffic safety, it is important to develop the following services:

- automatic monitoring of compliance with traffic rules;

- warnings about traffic jams and repair works, recommendations on detour routes;

- notifications about weather conditions and the condition of the road surface;

- systems of traffic sign recognition, lane keeping support, automatic speed limit, adaptive cruise control, dangerous approach warning, etc.;

- control of movement modes using variable value signs;

- monitoring and management of dangerous goods transportation;

- monitoring and traffic management in tunnels, on bridges and expressways.

Safety management in cities should be based on the principles of safety management strategy as such, which:

- formulates a safety strategy for the urban area as a whole;

- integrates safety with other urban strategies (for example, municipal transport development, land use planning, safer routes to schools);

- takes into account all types of road users;

- considers the functions of different types of roads;

- integrates existing measures to reduce injuries during the operation of the street and road network;

- takes advantage of opportunities where other areas and strategies to improve safety can help (for example, increasing safety as part of a city reconstruction project);

- encourages all professional groups to help achieve safety goals;

- protects against a possible adverse impact on the safety of other measures implemented as part of the city's development;

- encourages residents and all road users to be responsible;

- tracks progress toward security goals.

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RESEARCH OF THE USED ELECTRIC VEHICLES PRICE DEPENDENCE ON THE TECHNICAL AND OPERATIONAL INDICATORS

The number of electric cars is growing rapidly around the world, reaching 9.9 million [1] at the end of 2020. In Ukraine, the increase in the number of electric cars is not as significant as in Europe, the US and China, but there is a significant increase in their number, as well as an expansion of the charging station network. As of January 1, 2022, their number amounted to 33,592 cars [2], which is less than 1% of the total number of all passenger cars. The most common models of electric cars in Ukraine are Nissan Leaf, Tesla Model 3, Renault Zoe, Volkswagen E-Golf, Chevrolet Bolt, and others [3]. The main problem with the use of electric cars in Ukraine is the underdeveloped infrastructure, in particular, the lack of charging stations for rechargeable batteries.

The price of electric cars in the secondary market significantly depends on their brands and key technical and performance indicators, such as operation time, mileage, electric engine power, battery capacity, power reserve and technical condition.

After the start of operation, the price of a used electric car decreases and depends mainly on the residual life of its main components, including the car body, traction battery, electric engine and power electronics. In the first years of operation, the price of an electric car is close to the market price, and its decline is not so small. This is followed by a period of uniform price reduction to a level almost 2-3 times higher than the residual value of the materials from which the electric car is made. At the end of the operation period, the price reduction is not as significant and tends to the residual value of the electric car materials. The residual life of a car is classically determined by mileage, but the factor of operation period (age) is also important, because when an electric car is idle for a long time, chemical reactions still occur in the lithium-ion battery, plastic and rubber parts age and lose their performance, and parts corrode. All these processes follow an exponential law depending on the car age. On the other hand, the wear and tear of mechanical gears and bearings depends mainly on the mileage. The decrease in their service life also follows an exponential law depending on the mileage. Therefore, if the annual mileage of an electric car varies within a small range, the reduction in its price should follow an exponential law depending on its age.

Previous studies, an analysis of the dependence of the price of used electric cars of the Nissan Leaf brand, the most common in Ukraine, on age, mileage, electric motor power, traction battery capacity

and power reserve [4] according to the AVTO.RIA website was performed. Also, similar studies for the Tesla Model 3 and Renault Zoe brands, which supplemented these studies, are relevant.

The purpose of the work is to determine the impact of the main technical and operational indicators on the price of used electric cars in the secondary market of Ukraine based on the analysis of information from the AVTO.RIA website.

The main indicators of electric cars that were analysed according to AVTO.RIA website are price, operation period (age), mileage, electric engine power, battery capacity and power reserve. The information was analysed as of January 28, 2023, throughout Ukraine for the Nissan Leaf, Tesla Model 3 and Renault Zoe electric car brands.

The research was performed in the following sequence. Offers for Nissan, Tesla Model 3 and Renault Zoe electric cars were selected on AVTO.RIA website and divided into pages of 20 offers each. One electric car was selected from each page using an online random number generator (https://generator-online.com/uk/numbers/). If the selected offer turned out to be a car that had been in an accident, the price of which could potentially not adequately reflect the general trends depending on technical and performance indicators, such an offer was rejected. Also the offers that did not contain the indicators selected for analysis were excluded. In this case, another random number was generated for this page to select one from the group of 20 electric cars. From the obtained data sets a regression equation was obtained for the dependence of the electric car price on the main technical and performance indicators.

According to the data obtained, the linear regression analysis results excluded insignificant factors and obtained regression equations for calculating the price of used Nissan Leaf, Tesla Model 3 and Renault Zoe electric cars depending on age, mileage, engine power, battery capacity and power reserve

$$\text{Nissan Leaf} \qquad P = 7306{,}6 - 706{,}3A + 27{,}4W + 68{,}4E + 44{,}8D, \text{ USD}, \tag{1}$$

$$\text{Tesla Model 3} \qquad P = 21766 - 1350{,}7A - 45{,}1L + 37{,}5W + 22{,}8D, \text{ USD}, \tag{2}$$

$$\text{Renault Zoe} \qquad P = 17238{,}5 - 969{,}7A + 10{,}5L + 57{,}2E + 6{,}0D, \text{ USD}, \tag{3}$$

where P is the electric car price, USD; A is age, years; L mileage, thousand km; E is battery capacity, kWh; W is electric engine power, kW; D is power reserve, km.

The correlation coefficients for the obtained dependence are 0,813-0,957, which indicates a close relationship, with an average error of 5,8-7,4%.

The coefficient values before each factor indicate the magnitude of their influence on the formation of the used electric cars price, and the sign indicates a positive or negative impact as the value of the factor increases.

Each subsequent operation year of a Nissan Leaf electric car reduces its price on the secondary market by 706,3 USD, a Tesla Model 3 electric car by 1,350.7 USD, and a Renault Zoe electric car by 969,7 USD. In percentage terms, the price of Tesla Model 3 decreases by 3,8% per year compared to the

average (the study period was from 1 to 6 years), while the price of Nissan Leaf decreases by 4,9% (the study period was from 1 to 11 years), and Renault Zoe decreases by 5,3% (the study period was from 1 to 9 years).

Every 10,000 km of mileage reduces the price of a Tesla Model 3 by 451 USD, and a Renault Zoe by 105 USD. All other parameters studied increase the price of electric cars on the secondary market. Taking into account the possible ranges of changes in the parameters that contribute to the increase in the price of electric cars, the most significant impact on its value is the power reserve. Every 10 km of power reserve contribute to an increase in the price of a used electric car of the Nissan Leaf brand by 448 USD, a Tesla Model 3 electric car by 228 USD, and a Renault Zoe electric car by 60 USD.

The price of electric cars is most significantly affected by their age (Fig. 1). There is a medium and close relationship between these parameters with a correlation coefficient ranging from 0,58 (Tesla Model 3) to 0,92. This is due to the fact that in the first years of operation, car owners tend to sell electric cars at a price close to the purchase price in the primary market.

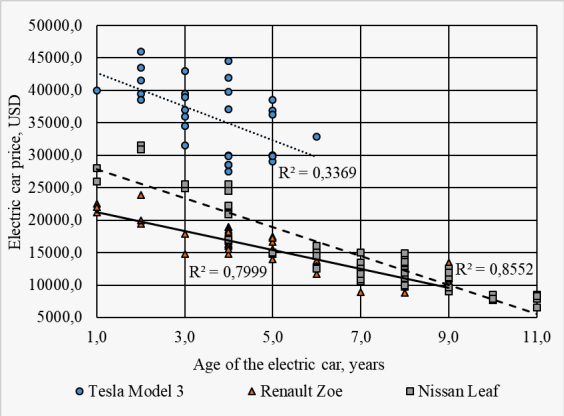

Fig. 1. Dependence of used Nissan Leaf, Tesla Model 3 and Renault Zoe prices on age

As a result of the study, regression equations were obtained showing the dependence of the used electric cars price of Nissan Leaf, Tesla Model 3 and Renault Zoe brands on the operation period, mileage, electric engine power, battery capacity and power reserve, which can be used to verify the adequacy of price offers in the secondary market.

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DESIGNING OF THE INTERSECTION FOR TRAFFIC SAFETY

Motor roads play a crucial role in driving the economic development of Ukraine and the global community. Road intersections represent pivotal components of the road network, influencing capacity, service quality, and safety. These are locations where traffic flows intersect, constantly altering the road dynamics [6].

In the foundational principles of the Ukrainian Road Traffic Code [2], an intersection is defined as "the point at which roads on the same level cross, meet, or diverge, with the boundary defined by the imaginary line between the beginning of the curbs on each road."

Intersections fall into two primary categories: those without priority traffic and those with priority traffic. In intersections without priority traffic, the right of way is granted to vehicles on the right. Intersections can have various configurations, including three, four, or more entry points, with different layout solutions. In contrast, at intersections with priority traffic, right of way is controlled through road signs, markings, and traffic lights.

Roundabouts, also known as circular intersections, are a specific type of intersection where traffic slows down and follows a one-way flow around a central island. These are commonly referred to as roundabouts. The emphasis on safety and high capacity has led to a notable increase in their prevalence. Conversely, when existing intersections become inadequate to meet the growing demand for transportation services, they may be transformed into other types [5].

In practical terms, there exists a variety of intersection types. The standardization of intersections is often constrained by factors such as local traffic conditions, construction costs, available space, and the societal implications of their implementation.

Intersections are of different types, each of which provides for the safe organization of the movement of vehicles. The sequence of actions for safe driving includes: choose the correct traffic lane, considering road markings and traffic signs; decrease the vehicle's speed; identify the intersection type and the presence of traffic light regulation; assess the road conditions for safely crossing the intersection; determine if there is a right of way or if you need to yield to other road users; halt the vehicle in the suitable lane, while being prepared for potential changes in the situation; safely navigate through the intersection.

An important condition for safe passage is its visibility and geometric boundaries, which should be easily recognizable. Here are the basic guidelines for navigating a roundabout intersection. When approaching the roundabout, you should select the correct lane, yield to vehicles already inside the

roundabout, and enter it, ensuring a safe maneuver within a safe gap in the traffic flow. The access capacity at the entrance is a similarly crucial operational element of a contemporary intersection. It is established by the traffic organization and the geometric layout of the intersection.

Roundabout intersections are crafted in various dimensions, each tailored to specific objectives and operational circumstances. For instance, compact roundabouts (with diameters of up to 25 meters) effectively curtail speeds and enhance safety, while larger roundabouts (exceeding 40 meters in diameter) offer greater traffic capacity [3]. Conflict scenarios at intersections can arise due to significant disparities in traffic flow speed and volume, along with issues related to right-of-way. Consequently, it is imperative, from a safety standpoint, to implement measures that regulate and reduce speeds at intersections or in their proximity. Evidence has demonstrated that roundabout intersections mitigate traffic congestion by eliminating left turns, allowing drivers to exit smoothly by making right turns. Design Engineer Amarnath Acharya outlines the following pros and cons of roundabouts. They are regarded as safer than traffic-controlled intersections due to factors such as reduced speeds of approaching and circulating vehicles, regulated by both road design and traffic signage. However, the downsides of circular traffic intersections include the necessity for a larger physical footprint compared to signal-controlled intersections and a greater number of maneuvers and speed adjustments during passage [1].

It is necessary to structure traffic management use a formalized general scheme based on classical principles of building complex technological control systems processes, including road traffic (Fig.1)

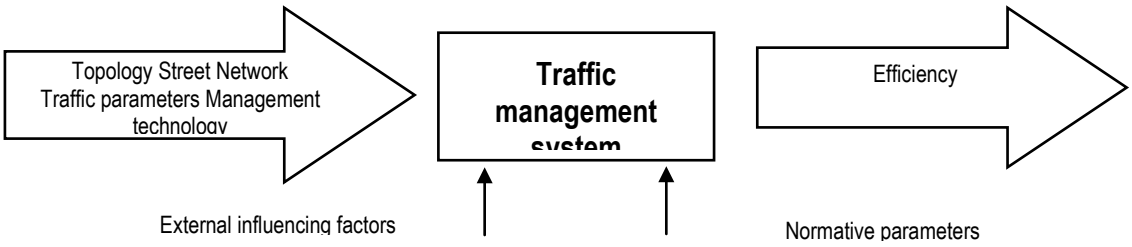

Fig. 1. Traffic management process

The mathematical dependence of functional interaction has a great influence on the development of control algorithms aimed at improving the quality and socio-economic indicators of road traffic. In order to streamline the management of traffic, it is essential to adhere to a formalized overarching framework, which draws from the classical principles of managing complex technological processes, road traffic being one of them. Within this framework, the adjustable parameters of traffic flow are under control, technological management parameters serve as the governing factors, external disruptions present critical scenarios, and changes in road conditions are internal factors. Normative parameters play a regulatory role in overseeing the execution of the traffic management process and are incorporated into the organizational structure of the system [4].

The arrangement and coordination of technical tools for managing and controlling road traffic (both vehicular and pedestrian) encompass a range of elements, such as road signs, informational signs, road markings, signal posts, various types of traffic and pedestrian barriers, traffic lights, video surveillance, and more. The traffic organization plan for a roundabout intersection, illustrating the positioning and interconnection of these technical tools for traffic management, can be represented as follows (Fig.2).

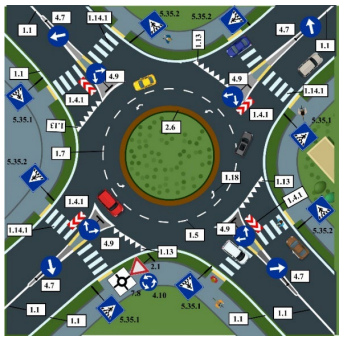

Fig. 2. The scheme of traffic organization of the intersection with circular traffic

The organization of intersection passage involves various categories of road signs, including priority, mandatory, informative, and indicative signs. To facilitate pedestrian movement around the intersection, sidewalks and designated crosswalks are incorporated. A video surveillance system is employed for traffic monitoring, comprising four cameras installed at the intersection. These cameras feature pan and zoom capabilities, as well as remote control from the Control Center. Despite the intention of traffic control devices to minimize conflicts, it's essential to acknowledge that they cannot entirely eradicate them due to deliberate violations of traffic regulations by both drivers and pedestrians.

Thus, each intersection of traffic possesses distinctive attributes that can influence its safety and travel convenience, as substantiated by research conducted by various scientists. Such intersections necessitate meticulous planning, considering the unique road conditions and future operation.

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Scientific edition

INNOVATIVE DEVELOPMENT OF RESOURCE-SAVING TECHNOLOGIES AND SUSTAINABLE USE OF NATURAL RESOURCES

BOOK OF ABSTRACTS

First publication

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