THE NEW WAVE OF TECHNOLOGICAL INNOVATIONS FOR SUSTAINABLE DEVELOPMENT OF GEOTECHNICAL SYSTEMS

David Kaplunov[1], *Marina* Rylnikova[1*] and *Dmitry* Radchenko[1]

[1]Institute of Complex Exploitation of Mineral Resources of the Russian Academy of Sciences, Moscow, Russia

Abstract. Today the development of information network technologies and the new equipment determine the new strategies in the designing ore deposits exploration with elements of artificial intelligence, software system processing of the geodata, high-precision methods and tools for studying the mineral matter and the structure of mine massifs, renewable energy, and green technologies. In addition, these components are used in the sustainable operations of mine technical systems, for the active expendable of which it is necessary to make a transition to a new technological setup. It is associated with the capabilities of operational synchronous transformation of the taping resources and the adaptation of geotechnologies to specific conditions, to meet the needs of society in georesources.

1 Introduction

In modern world, the trends determine the assigning of a new technological setup of mining production that are notable in the development of information network technologies in the field of development of mineral deposits. The use of machines with artificial intelligence; in systems for obtaining and processing geodata and others are also important.

The development of mining machinery production for the autonomous operation of mining transport means has already prepared a transition to a new technological setup with in unmanned mode, and equipping mining machines with elements of artificial intelligence [1-6]. In the coming years are expected a reducing risk factor of human presence in mining operations dangerous zone. They are the development-cutting heading and breakage faces the zones of intensive massif deformation, including dynamic manifestations of strata pressure, in areas and an increased radioactive background, with unfavorable environmental conditions. High or low temperature of the rock massif, with atmospheric gas pollution, low oxygen content or atmospheric pressure [7, 8] are also important factors. The possibility of mining the mineral products in such zones "with zero input" without reducing of the appropriate in resource development is the key factor in the tap resources in mining. It will characterize the new technological setup of mining in general. In particular, the equipment properties description for composition, structure and condition of the rock massif get to the

* Corresponding author: Rylnikova@mail.ru

new level. Even today, in real time mode at on open-cast the acquisition of collecting and processing information on the stability of open-pit slopes and dumps with the use of georadars are carried out. Therefore, establishment of patterns changes in the state of rock massifs [9, 10 etc.] is being performed also. At the same time, the accuracy of prognosis of landslide phenomena and voids is significantly growing. In the nearest future the appropriate systems will be installed in underground mines. On-line sensors are being introduced to assess the quality of mineral and raw materials stream – ores and rocks, mine waters, filling mixtures and ore processing products. Information of the mine atmosphere the composition is constantly obtained at to the dispatchers' panels. In our paper we describe the software complexes that can capable to estimate accurately the duration of sustainable operation of virtually, technical structure, formed underground chambers to be developed. The development of recommendations to ensure the long-term stability in the dynamics of changes in gas and hydro-mechanical conditions were carried out successfully. In developed countries, renewable energy systems are being introduced in mining industry.

2 Methods

The parameters of the technologies making the new technological setup should be in the form of a single complex adapted to the specific conditions for the development of deposits of solid minerals. Adaptation refers to the operational synchronous transformation of geotechnologies to the properties and condition of a technogenic transformed site of subsurface resources. The changing needs of society regardless to the direct objectives of extracting minerals from the earth interior should be also taken into account. However, the performance of the new technological setup based on the adaptive systems development and technologies is "tailored" to meet the needs of social development. It is a very relevant objective, which was greatly developed in recent years in various fields of human activity. [11, 12]. Thus, at present, there is rapid increase in technological development recorded in the field of mining sciences in implementation of the self-propelled machinery and high-performance mining equipment complexes installed in mines. The possibility of obtaining unlimited volumes of initial data and their processing for adjusting the parameters of geotechnologies, mineral and raw materials flows, formed mine technical designs shows the necessity to shift to a new technological setup. There may become adaptive geotechnologies, when the stages of transition from one type of geotechnology to another in the course of development deposits will be designed including the period after mining operations [13]. Of course it will require the establishment of fundamental regularities and the justification for the stages of the transition to a new technological setup of the sustainable operation of underground mines. It should be based on the establishment of spatio-temporal interrelationships of technological processes in the development and conservation of subsoil.

3 Scientific and methodological basis of research

Creating the scientific basis for the technical re-equipment of mines providing the transition to a new technological setup is related to:

- the exhaustion of the traditional mineral resource base, available to humanity even 10 years ago, due to the long-term implementation of extensive subsoil use concept;
- the transition of the world community to the operation principles of sustainable development of nature and society (the Paris Agreement regulating the measures of reducing carbon dioxide in the atmosphere from 2020 instead of the Kyoto Protocol);

- the large-scale research in the field of intellectualization of the mining complex, renewable energy, the use of equipment and materials of the new generation, the widespread development of combined physical-technical and physical-chemical geotechnologies. Nevertheless mining complex functioning on the principles of sustainable development is associated with unprecedented conditions: the increasing of mining operations depth; the reduction of large-scale deposits of solid minerals with high quality of raw materials; the decrease of valuable components of in the content in ore and increase of harmful impurities; the increase of rebellious ore share; the accumulation of large volumes technogenic formations, comparable to volume of accumulated metals with of promising deposit reserves; the displacement of mineral resource development sites in hard-to-reach areas with undeveloped infrastructure and unfavorable natural and climatic conditions; the leaving of significant volumes of natural and man-made reserves in the depths of the Earth located in complex technogenically altered geomechanical, gas-hydrodynamic and mine technical conditions; the growth of the requirements to the quality of products by the world market; the increase in specific energy costs and others. In this connection sustainable development should be understood not only as a classic definition, implying such a kind of development that allows to ensure the existence of society without threatening to future generations to meet their needs [14-18]. Sustainable development of mining complex should be understood as a set of strategic initiatives to ensure the exploitation of each developing subsoil area for indefinite period time on the basis of the initial design in the stages of transition to a new technological structure of field development. It is performed not only for the development of balance reserves but also for the period after mining of minerals is completed. At the same time the traditional "trilemma" is kept consisting in ensuring the balance of economic, environmental and social components (Fig. 1).

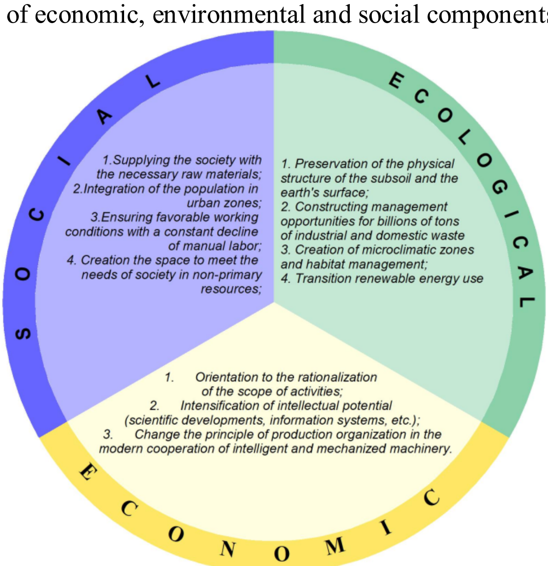

Fig 1. The relationship of sustainable development aspects of mining complex in transition period to the new technological setup

In summary the ecological component of sustainable development comprises:

- the preservation of the physical subsoil structure and the earth surface to maintain the structure, substance and physical fields of the stability in biosphere processes;

- the implementation of management opportunities controls billions of tons industrial and domestic waste, complete ecologically safe utilization of which is possible in the developed mined-out spaces;

- the creation of microclimatic zones and habitat management in the developed underground space of mines depending on its functional use;

- the transition to the use of renewable technogenic energy sources, formed in the implementation of technogenic subsoil transformation processes.

The social component of sustainable development of mine technical systems is:

- supplying the society with the necessary raw materials;
- population integration in urbanization zones;
- ensuring with favorable working conditions by a constant decrease of manual labor share and the influence of the human factor to the implementation of the tap resources processes;
- creation of space to meet the needs of society in non-energy resources - transport communications, location of industrial production, the deep urbanization, etc.

The main design task is the preservation of the production capacity not only for metal products, but also for all natural and technogenic geological resources involved into operation, with an acceptable level of profitability. This requires the economic mechanisms for technical re-equipment. Achieving such goals and complicated tasks may be possible only on establishing regularities and determining the conditions for the transition to the new technological setup of design, comprising the following strategies for the technical re-equipment of the mines (Fig. 2):

- the combining physical-technical and physical-chemical geotechnologies for the most efficient field development [18, 19];

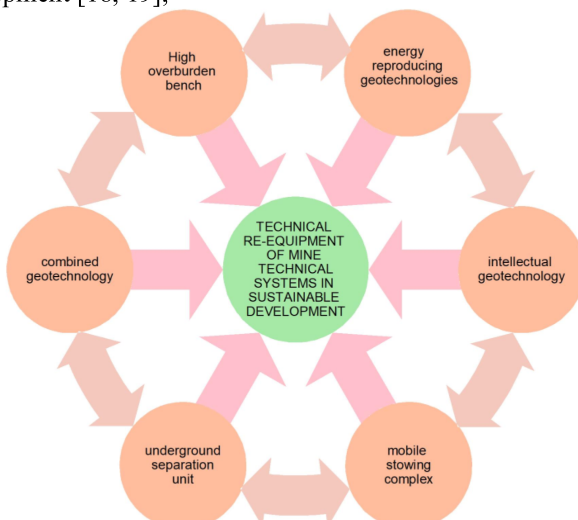

Fig 2 - Strategies for the technical re-equipment of mines for the sustainable operation of mine technical systems

- the change in the part of specifications in open mining operations on the basis of a proper transition to high overburden bench;
- the introduction of energy production technologies using technogenic sources;
- the introduction of equipment with elements of artificial intelligence, capable to operate without human involvement in particularly hazardous areas of quarries and underground mines;
- the use of underground moving or mobile stowing complexes designed for the utilization of rocks from the excavation of mine workings and wastes of internal separation. It is determined for the effective erection of artificial structures with various purposes in the multifunctional use of the mined-out space;
- the use of mobile inter-mineral equipment providing management of the volumes and quality of mineral and raw materials flows. It is possible with the winding to the surface only the amenable ores or even marketable metals, according to the principle "do not get out anything superfluous".

4 Results and discussion

The Institute of Integrated Development Problems of Subsurface Resources of the Russian Academy of Sciences develops technologies designed to provide a new technological setup of mining production in the interests of sustainable development of mining. Some parameters of geotechnologies and the conditions are considered for their implementation in the above mentioned 6 interrelated strategies of transition to a new technological setup.

The combination of physical-technical and physicochemical geotechnologies is the sphere of interests in the field of integrated development of copper-bearing raw materials in the Urals, polymetallic lead-zinc ores of the Caucasus, gold-bearing and uranium ores of the Urals, Siberia, the Far East. Problems of the development of combined physical-technical and physical-chemical geotechnology are currently relevant for the development of diamond pipes by ALROSA, iron ore provinces of the KMA and the Kola Peninsula, and others. Reduction in Cu content is less than 0.5%, Zn is less than 1%, Au is less than 1 g / t and so on. It does not leave an alternative in developing deposits to a combination of open and underground mining operations with various methods of leaching separately prepared ore and the technogenetics solids. A similar situation is abroad [20-22].

Restructuring the reserves to be developed in future, the new trends in the development of open and underground mining should be highlighted. Undoubtedly, the most important strategy of improving open mining is their transition to high overburden bench. It is important to note that the increase in the height of the bench provides the increase in additional extracted reserves, the growth of production capacity in the open-pit increase its final depth. The reduction in the length of the transport routes is also the advantage. The reduction in time for the track side of transport and equipment, the reduction in the number of working decks, reloading points, improvement of the logistic scheme of the mine, the reduction in the amount of equipment in the quarry, the reduction in technological processes may also be performed to advantages. Improvement quality of crushing of the rock is due to increase of operation time explosion of the solid in presence broken-down rock of collapsed rocks. It generally provides the reduction of the negative impact in mining operations to the environment with reducing the number and volume dust and gases and other emissions [23]. It has been proved by the researches that the timely transition to open mining operations by high benches in the period of maximum development of mining operations, provides the increase in the final depth of the quarry and the increment of additional reserves without beating the open pit sides with the current ratio of overburden to economic stripping ratio being equal.

The urgency of researching the conditions and parameters in the application of energy-efficient geotechnologies in the integrated development of ore deposits is due, on the one hand, to the increase in the energy consumption of mines with an increase in the depth of mining (the share of energy costs in the cost of solid minerals is 45-50%), the growing interest in the world to the receiving the and use of renewable energy sources. The share of renewable sources is one of the main indicators of the national economy progressiveness in the overall balance of energy resources. In addition, assessing the energy potential of internal streams of hydraulic mixtures, it is established that they represent an independent group of technogenic energy geo-resources to be realized and usefully used only in the mine technical system. This is a new group of renewable technogenic energy sources (RES), which potential was not taken into account before in the world energy sector. It is determined that, alongside with the increase in mining operations depth, the conditions and opportunities for the beneficial use of renewable energy sources are increasing from the flow of mine water and other hydraulic fluids. This determines a significant renewable energy sources from the mine water streams and filling the mixture at deep levels of ore deposits and provides a significant reduction in the ore extraction energy intensity [24].

It is pertinent to note here that the final extraction of reserves in previously developed large deposits, can now be conducted only on the basis of robotic intellectual geotechnologies the conditions for the development of which are characterized by the increased complexity of mining, So assessing the parameters of intellectual geotechnologies, it was established that the mine technical system previously designed was based on conditions and constraints and associated with human working conditions. Henceforth, with the development of remote and robotic geotechnologies, self-contained means of monitoring the state of the solid and their combinations supports the substantiation of parameters only to ensure the conditions for robotic and autonomously controlled equipment in the zones of direct mining operations. The removal of hygiene requirements for human operation in these zones, as well as the restrictions and requirements of industrial safety, will determine new requirements for the formation of mine technical systems and the justification of the parameters of the habitat in the mine technical system and the areal of its influence. The use of mobile stowing complexes contributes into the rapid utilization of hardening filling mixtures from the stage of excavating of mine workings without winding them to the surface [25]. Small-sized equipment of stowing complexes is mobile and can move along the underground workings after the development of the extraction front. Crushing of rocks is performed in inertial crushers of the new generation with output at least 30% of the class minus 0.074 mm, providing the necessary transport ability of the mixture, as in the case of mill grinding. As a consequence, the length of pipeline transport is reduced. The latter contributes to the involvement in the development of deposits of various sizes and forms of occurrence and increase the efficiency of filling underground voids. Filling mixtures obtained in experimental industrial conditions are characterized by favorable rheologic properties (lowability spread over the cone of StroiNsIL 18-21 cm) and lower moisture consumption. Water consumption is 15-20% lower than in traditional mill grinding at plants. Mixtures are characterized by the acceleration of the hardening time and development of strength. A wide range of equipment size allows to form modular-type stowing complexes in accordance with various production requirements. The operation of the equipment in a direct (open) cycle ensures the minimum of energy consumption. Along with the high energy efficiency, the complex of equipment has low steel intensity and does not require the construction of stationary foundations. Thus with the advent of underground mobile stowing complexes, a new meaning of the technology of internal separation of ores was acquired. The ability to prepare hardening filling mixtures directly in a subterranean mine solves the problem of utilization of ore mining and separation waste that can be effectively used to prepare filling mixtures without being dispensed to the surface. As a result, up to 40% of waste separation can be left in the earth interiors. In modern conditions, when switching to the development of deposits of halving previously classified as non-commercial, the combination of these two separation and bookmarking technologies with the use of mobile complexes provides the very possibility of mastering a number of large mineralization characterized by a low content of valuable components.

The contribution of the mining complex of developed producing countries to sustainable development is represented in the implementation of a technologies set making up the new technological setup of mining. The current state of the mining industry determines the prospects for the development of combined geotechnologies based on the use of equipment with artificial intelligence components operating in "unmanned" zones of deep quarries and underground mines. The introduction of these technologies implies the use of a set of mobile and portable equipment for mine separation, filling mixtures, the production of electricity from the renewable technogenic sources formed in the processes of technogenic subsoil transformation. This study presented interrelated geotechnological processes, the implementation of which provides the formation of the new technological order in mining industry.

5 Conclusions

The study of the conditions for the transition to a new technological setup shows that only on the basis of the interrelationship between intellectual technologies and new equipments, with elements of artificial intelligence, geodatabase software complexes, high-precision methods and tools for exploration subsoil matter, the structure and condition of rock massifs and renewable energy define the new strategies in the design of the development of ore deposits. Content components are of the technical systems of the sustainable operation in mine, for wide practical application of which requires a transition to a new technological setup. It is associated with the possibilities of operative synchronous transformation of geotechnologies to the specifications of the developed site in subsurface resources, taking into account the needs of society in geo-resources.

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