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INFORMATION TECHNOLOGIES IN DESIGNING MINING OBJECTS

The research is aimed at improving forms and methods of information support of technological measures for efficient mining and complex usage of mineral resources at mining enterprises' functioning stages.

Methods. The issue of information support is studied by analyzing literature sources concerning the advanced experience data, results of studying the ore-bearing massif, parameters of deposit mining, technological properties of ores, evaluating the massif state by complex methods using models and statistics data.

Scientific novelty. There are developed basic principles of designing mining processes based on concepts of simulation databases, expert and geoinformation systems in ore mining and initial processing by applying new technologies of production processes at the processing stage.

Practical significance. Application of established system connections and regularities allows formalizing principles of interaction between a designing body, users and exploitation objects on the basis of analysis and synthesis of the system of controlling a design error risk and working out a model of managing mining production aimed at increasing mining efficiency and safety by correcting impacts at all stages of an object's existence.

Results. The research provides evaluation of the information support state of a modern mining production focused on solid mineral mining by conventional and up-to-date technologies. There are formulated basic aspects of information support improvement. The authors suggest schemes of multi-variant automated designing with step-by-step optimization of particular solutions of automated designing which implies mineral deposit development, project evaluation as to its conformity with environment-saving demands, continuous monitoring of processes accompanied by controlling solutions at deposit mining stages. There are recommended methods of investigating new processes of metal extraction from substandard raw materials.

Keywords: information support, mineral resources, mining enterprise, analysis, technology, ore, designing, imitation simulation

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Introduction. Under conditions of the system economic crisis increasingly affecting the mining industry, the problem of rational usage of mined mineral resources is becoming urgent.

The latest achievements and publications concerning basic principles of solving the problem indicate that mining objects' efficient designing is impossible without reliable information support as decision-making calls for formation of a diverse data bank and is hindered by underdeveloped methods of data formalization. That is why, the majority of mining enterprises apply computer information systems based on concepts of databases, simulation modelling, expert and geoinformation systems [1-2].

In mining, to a greater degree than in other industries, the necessity of applying geoinformation technologies is explained by minimal consumption of material and labour resources, complete and complex usage of mined resources, protection of general natural resources and the increased risk of mining operations.

Information technologies forecast development dynamics and optimize industrial processes including:

mining the quantity of ores necessary for meeting the demands of metallurgy;

ensuring competitive economic indices in conditions of market formation;

providing safe and comfortable conditions for people and environmental ecosystems.

A mining enterprise is a sum of capital, prospecting, preliminary and stoping mine workings, means and mechanisms of transport, hoisting, ventilation, mine pumping, ore concentration, storage, etc. Connection and interrelation of the system elements are controlled by technical and economic indices of its functioning. The search and order of management processes are organized sequentially, sequentially and simultaneously and by the cyclical iteration method using automation means.

A mining enterprise's goal achievement is hindered by natural and technological factors among which the major role is played by natural ones including the substantial variety of ore deposits' parameters. The designing process means optimization of enterprise management, parameters and technologies of development and stoping mining processes.

The level of a mining enterprise's information support is high enough, yet, little attention is paid to issues of operational and immediate correction of certain aspects of a general problem, especially loosing by means of blasting and leaching metals from substandard raw materials [3-4].

Thus, the current research is aimed at improving forms and methods of information support of technological measures for efficient mining and complex usage of mined mineral resources at mining enterprises' functioning stages.

Materials and methods. Analyses of the information support issue are performed on the basis of literature sources concerning the advanced experience data, results of studying the ore-bearing massif, parameters of deposit mining, technological properties of ores, evaluating the massif state by complex methods using models and statistics data.

Russia's mineral base development is aimed at meeting increasing demands and enhancing competitiveness of domestic mining enterprises.

Accelerated obsolescence of the major production stock (the renewal coefficient does not exceed 2% with the minimum level of 4-5%), the constant growth of prices for dominant industries' products and services and the abrupt shortage of investments are the basic aspects of mining enterprises' competitiveness.

The Russian ore material base of the metallurgical industry is notable for complicated mining and geological conditions of deposit mining and a lower content of a number of metals in the natural raw materials compared to other countries that form prices for metallurgical materials.

These tasks can be solved by applying information technologies potential.

Designing of an underground mine as an optimal system of many variables implies a sum of optimization tasks for solving general and particular problems. Solution synthesis is a responsible operation and it is not always possible on the basis of a step-by-step and gradual approach to the required optimum.

In using information technologies means within the CAD (computer assisted design) system for solving a design task, a mathematical model characterizing an object under study and providing necessary and sufficient data is developed. Modelling means describing regularities of a certain mining object by means of mathematical expressions or models: correlation, net, game-based, programming ones and others.

A system of mining objects' designing is characterized by:

its single character due to correlations between separate links of a technological net;

compatibility of subsystem parameters within the data bank;

hierarchy of solutions within subsystems.

A complicated character of designing mining objects is conditioned by ambiguity of initial data, a multilink structure of management, a dynamic and discrete character of some mining processes in space-time and a diversity of possible solutions.

In the mining industry, computer-assisted designing with step-by-step optimization of particular solutions is a priority (Fig.1).

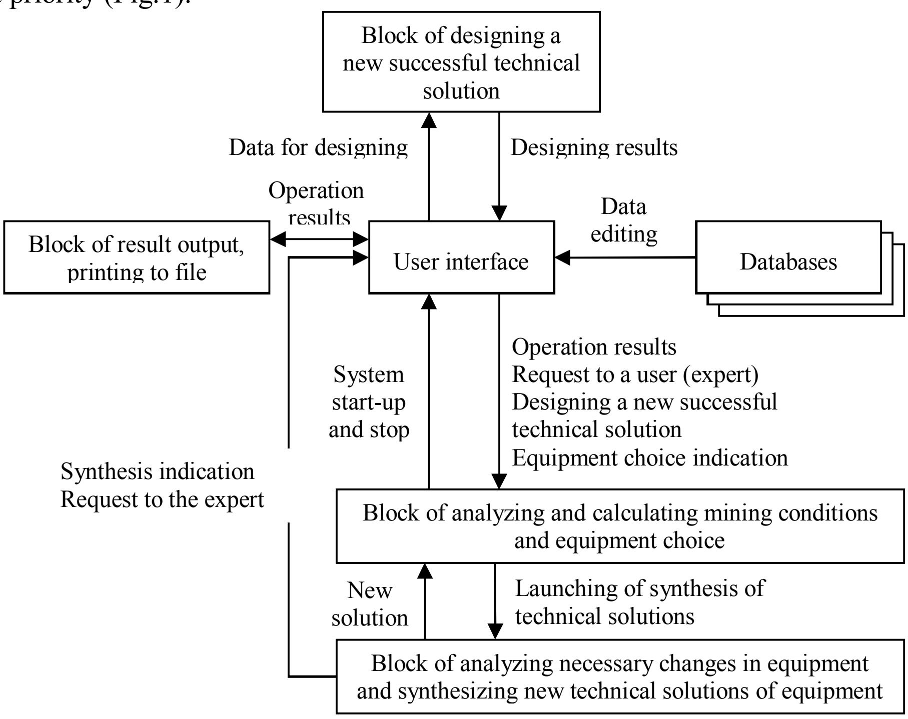

Fig. 1. Scheme of making designing solution

An underground mine's flow sheet is a sum of mine workings and mechanisms for loose ore dislodging, ore haulage to mucking areas, underground transport, hoisting and surface transport [5-6].

Each element of the control system is connected to the centre and the designed site by measurement and control automated means. Mining processes are accumulated, systematized, processed and displayed on the monitor.

A designed site is equipped with the means for modelling different variants according to various criteria that enables finding an optimization model with respect to its optimality in the shortest time impossible with other designing methods.

Graphic devices allow fixing and interpreting the CAD results in a form of projects. The main objective of the CAD is to work out a system controlling the massif geomechanics in underground mining (Fig.2).

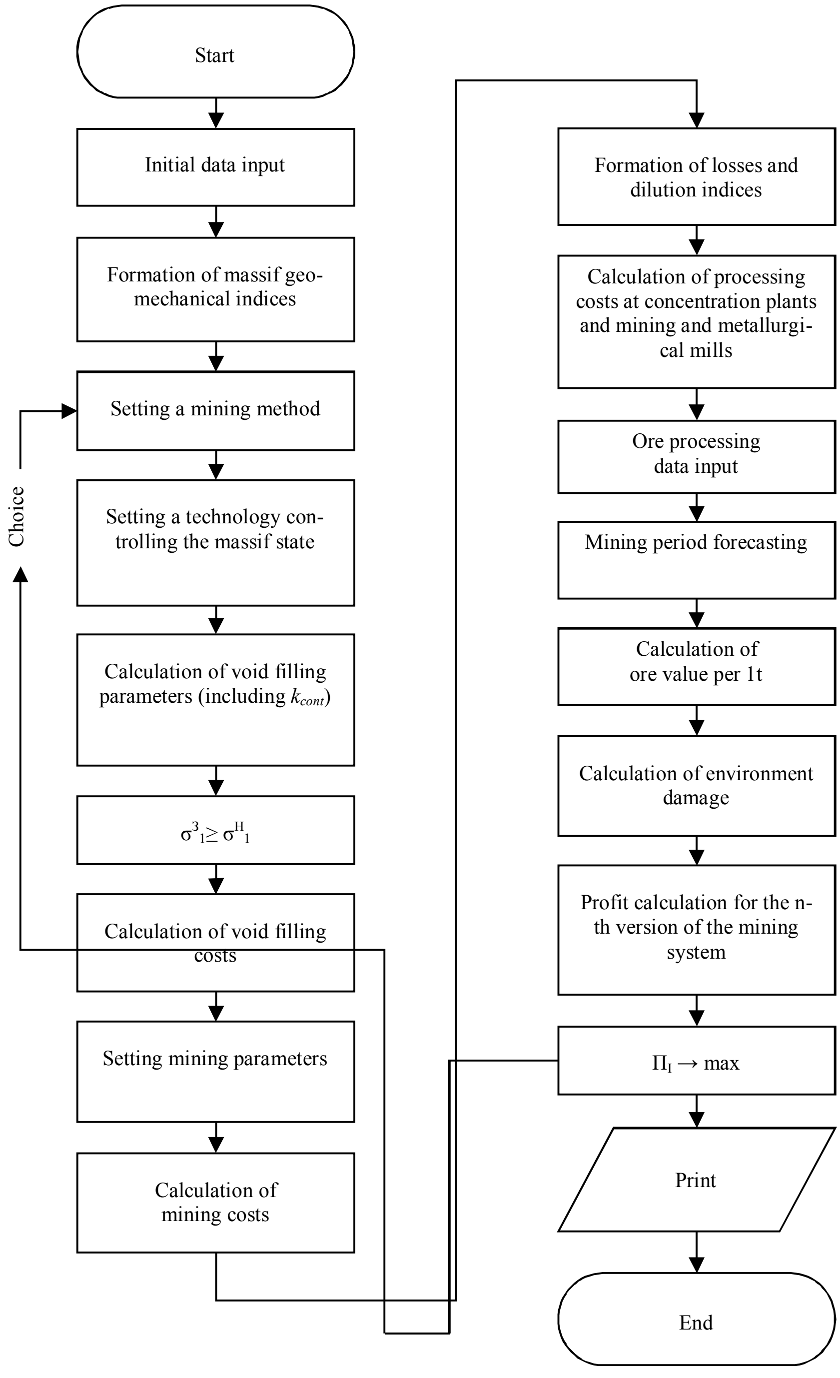

Fig. 2. Flow sheet of automated control of the massif state in underground mining

Designing is based on an enterprise's data bank which includes natural, technological and economic aspects.

The research methods for investigating a natural ore-bearing massif are based on the laws of kinematical and dynamic similarity of the processes occurring in rock massifs and in a laboratory [7-10]. In rock scanning, ultrasonic seismoscopes are used when an elastic wave passing through the massif is transformed into an electric pulse and directed to the electron oscilloscope. In scanning rocks, their physical and mechanical properties are investigated under the action of powerful microwave fields.

The de-stressing method applies the phenomenon of rock restitution after the connection with the massif is disrupted. The massif stressed state is evaluated by elastic deformation values during its de-stressing by the methods of elastic restitution of a blasthole face in core drilling and changes in the central hole diameter in a drilled core.

The acoustic method is based on the capacity of rocks to generate elastic sound pulses in changing the stressed state. The intensity criterion is the number of occurring sound pulses per unit time.

The ultrasonic method is based on measuring the velocity of elastic waves in the rock massif. With the increase of stresses, the velocity of elastic waves rises. When the massif is destroyed, it falls.

The electrometric method is based on the dependency between the electric conductivity of rocks and stresses. It works in highly porous rocks as it determines the conductivity of pore waters in rocks.

The seismoacoustic method applies the scheme in which excitation of elastic waves in rocks is generated by impacts. A piezo sensor gives a pulse to an activation former. Electric seismic detectors receive elastic oscillations passing through the massif and the signal goes to electronic commutators that provide the switch of the amplifier cascade outputs to the oscilloscope input. Amplification of elastic oscillations due to microcircuits and an amplified oscilloscope block prevents the useful signal distortion.

The rock density in the massif is determined by the method based on varied absorption and dispersion rate of gamma-radiation in media of various density.

Satellite geodesic methods applying GPS-receivers (e.g. "Trimble" and "Sokkia") provide data on surface deformations from one or two meters to dozens of kilometers.

In investigating geodynamic processes, there are applied coordinates of station points and control networks and the values of the Earth's crust deformations not only in the nearest area of the technogenic impact (rock displacement trough), but also in the farthest area affected by mine workings.

The stressed state is assessed by comparing the destruction sound pulses occurring in the massif per unit time with the basic value. A deformoscope measures the sonic pulse frequency by a geophone and sound-ranging equipment. The method allows acquiring data on the massif state accompanied by automated signal fixation.

The controlling device alternately puts into operation transducers of sonic pulses of eclectic signals and, via the remote switching blocks of the transducers, passes them to the amplifier and next to the recording device.

Under the automated mode, the time of switching on the power supply is determined and when it comes the clockwork switches on the power supply automatically. The controlling device inquires the sonic transducers in consecutive order for five minutes, records the data and is switched off.

The massif state is assessed by frequency sensors by means of blastholes of various orientation with respect to rock tectonic structures and mining direction and it allows creating a profile observation line. The frequency sensors evaluate the changes of the generated pulses frequency, the deformations go to the sensitive element and are recorded.

Dependencies between the coefficient of rock attenuation in the massif and their electric resistance are assessed by the electrometric method which detects the defects distorting the rock uniformity. The specific resistance of rocks in the massif is inversely proportional to their porosity and fracturing. The seeming electric resistance of rocks depends on geological characteristics. The measured differences of current potentials and strength in feeding electrodes provide the coefficient of the massif looseness which is applied to determining the areas of support pressure around mine workings, their dynamics and evaluating the impact of fractures on mine working stability.

Solid rock inclusions are detected by the difference of elastic waves propagation velocities in media of varied density. In indicatrix plans, the areas of high velocity values with respect to an average velocity are determined. Comparing the data of two indicatrixes in one plane, high velocity areas of direct wave propagation are distinguished. Areas of high velocities of elastic wave propagation indicate solid inclusions.

Rock deformations result in interaction of the "massif-support" system depending on sizes of the inelastic deformation areas around mine workings. The support displacement value is found by the relation of stresses in the mine working contour to the rock strength in case of simple compression.

The areas formation is controlled by measuring the displacements of deep and contour benchmarks at the gauge station. Deep benchmarks record rock displacements at the distance of 1.5m, 3m, 4.5m and 6m from the external support contour.

Technological properties are investigated by experiment.

To determine filtration non-homogeneity of rocks the following parameters are investigated:

the dependency of the elastic waves frequency on rock density;

the dependency of the elastic waves frequency on rock sizes;

the value of ore loosening.

Explosive charges are used to excite elastic oscillations. Oscilloscopes and sensors record strain waves. To record the shot break, along with the charge inside the blasthole, a sensor closed via the dc source to the oscilloscope galvanometer is installed. The sensors and the shot break indicate the time of the strain waves front moving along the massif. The front movement front and the distance from the charge to the sensor indicates the strain waves propagation velocity which is the criterion of the ore filtration capacity.

The same parameters are investigated by means of a model. The size scale of the model material is 1:50. The model consists of five sections – ventilation pipe segments. As long as the model is filled, the sections are connected. The sensors are installed every 0.3 m. Oscillations in the model are excited by an impact device. The impact pulse is synchronized with the oscilloscope switch by a time relay. The velocity oscillogram is represented graphically.

Solutions spreading is investigated on the stand bench of a pipe which is filled with ore of +5-10mm in size. The column is equipped with the bottom allowing division of the flow into several sections, each of them being characterized by some water speed and the rate of the space filling. The spreading areas are divided by cylinders located at the column base. They are welded to the perforated disc (the fake disc) and form (considering the column case) annular isolated receiving and feed chambers with the common bottom. The feed chambers have pipe nipples for draining the solution. The pipe nipple cross-section provides free water drainage. The backing of the bottom is excluded due to perforation. The solution quantity is controlled by a water tray.

The sites with complicated interaction of multiple-aged magmatic rocks, mineral associations and disturbances are designed at scales of 1:10 and 1:25. Mine workings are tested on both walls by vertical trenches. If the ore body thickness exceeds the mine working height, vertical boreholes are drilled every 5m to for contouring the ore body according to its thickness. The contoured cross-sections allow calculating the ore reserves. In opening up steep ore bodies by crosscuts and orts, both walls are tested by two horizontal trenches located 0. m and 1.5m from their ground.

Geophysical testing provides the data for ore body contouring. In the course of mining it is specified by blasthole logging. To find tongues and separate ore bodies 10m deep blastholes are drilled every 10m in chambers. Ore reserves are calculated by the method of geological blocks by categories C1 and C2. The reserves divided into exploitation blocks by development mine workings are blocked out ores. The blocked-out ores are the reserves in which industrial block reserves consider ore losses and dilution and ore extraction becomes possible.

The mineral mined-out reserves are calculated by monthly surveying measurements of areas and volumes. At the first stage, the exploitation block is contoured by drifts and raises. The distance between blast- and boreholes is 5-20m, the depth is 3-15m. At sites of irregular mineralization the block area is drilled by blastholes at 25m x 25m or 12.5m x 12.5m grid. The second stage exploration is performed during stoping operations within blocks. It is aimed at searching for tongues, determining mineralization on mine working walls and finding separate ore bodies. The bottom and the roof of stopes are drilled around by boreholes.

Ore quality indices are investigated by ore breaking within the standard contour according to the feasibility study. Considering the established ore contour, development workings are selected and exploratory boreholes are drilled. Borehole testing allows making geological cross-sections and distinguishing contour zones and the ore breaking contour.

At sites of simple structure, a contour zone is built along the contour of the ore body, at those of complicated structure, ore ledges are united by the external border and troughs inside the body contour – by the internal border.

Wasteless utilization is investigated at concentration tailings by means of a disintegrator [11-15]. The experiment is aimed at determining the parameters of metal components transition into a solution by leaching in a disintegrator.

An integrated leaching method is applied in the following modes:

1. Agitation leaching of non-processed tailings.
2. Agitation leaching of previously activated tailing.
3. Tailing leaching in a disintegrator.
4. Agitation leaching of tailings activated in a disintegrator.
5. Multiple tailings leaching in a disintegrator.

According to the Box-Behnken design, independent factors are as follows:

the sulfuric acid content in the leaching solution (X_1) 2-10 g/l;

the sodium chloride content in the leaching solution (X_2) 20-160 g/l;

the weight ratio of the leaching solution mass and the leached mass (X_3) in a single experiment (50g) 4-10;

the leaching time ((X_4) within 0.15-1.0 hours.

The quantity of tailings subjected to leaching in a single experiment is 50g. A previously prepared leaching solution of the specified composition is mixed with tailings at the first stage just before agitation leaching, on the second stage – after the leached material activation in a disintegrator, at other stages – before feeding to a disintegrator.

At the first and the second stages, agitation leaching of tailings with a solution in the form of a slurry obtained by adding the activated material to the leaching solution or in the form of a slurry obtained in tailings and the solution passing through a disintegrator is performed during the specified time with the constant and the same rotation speed. At the third stage the mixture obtained by adding tailings or the slurry into the leaching solution is fed into the disintegrator chamber. At the fourth stage, the mixture is also fed into the working disintegrator chamber and then it is leached for a specific time period in the agitator with the constant and the same rotation speed. At the fifth stage, the mixture of the initial materials with the leaching solution is run through the disintegrator the specific number of times, thus, increasing the activation time.

Basic percolation leaching is performed until the background content is achieved regardless of time. The combined activation lasts 60min. The experiment results indicate how activation of concentration tailings increases extraction of metals from tailings. Experiment results are interpreted mathematically in the form of logarithmical or polynomial interpolation.

The economic data bank is completed by calculating the costs for design implementing using the data of the technology application under similar conditions [16-18].

Results. Data on the system are used for correcting on all mining stages by continuous monitoring the processes accompanied by solution making according to the scheme (Fig. 3).

In the past, it took a long time to accumulate initial data and they soon became obsolete. At present, there are methods for calculating the parameters of mining operations on-the-fly.

In designing, basic indices are input into databases which allow developing software aimed at uniting the obtained data bases, analyzing their validity, calculating final indices from the differentiated contribution of each process and providing corresponding recommendations.

As finding an optimal solution means a complete overrun, it is advisable to apply the randomized search method, which performs local optimization with the solution time evaluation necessary for complete data overrun.

In mineral deposit mining, the parameters of technological processes should ensure the quality of the mined raw materials, economic efficiency and safety of mining operations. The criterion of the mined mineral quality is finding the plan in which the objective function is better than the functional which corresponds to the first random acceptable solution simulating the controlling impact.

The programme consists of an interface part ensuring a dialogue with a User and a calculating part containing the modules for determining the process parameters. The interface part provides the input, deletion and editing of demands and indices as well as regulates the composition and content of designs. It determines stope sizes, borehole location, charge design, muck pile geometry and mining safety.

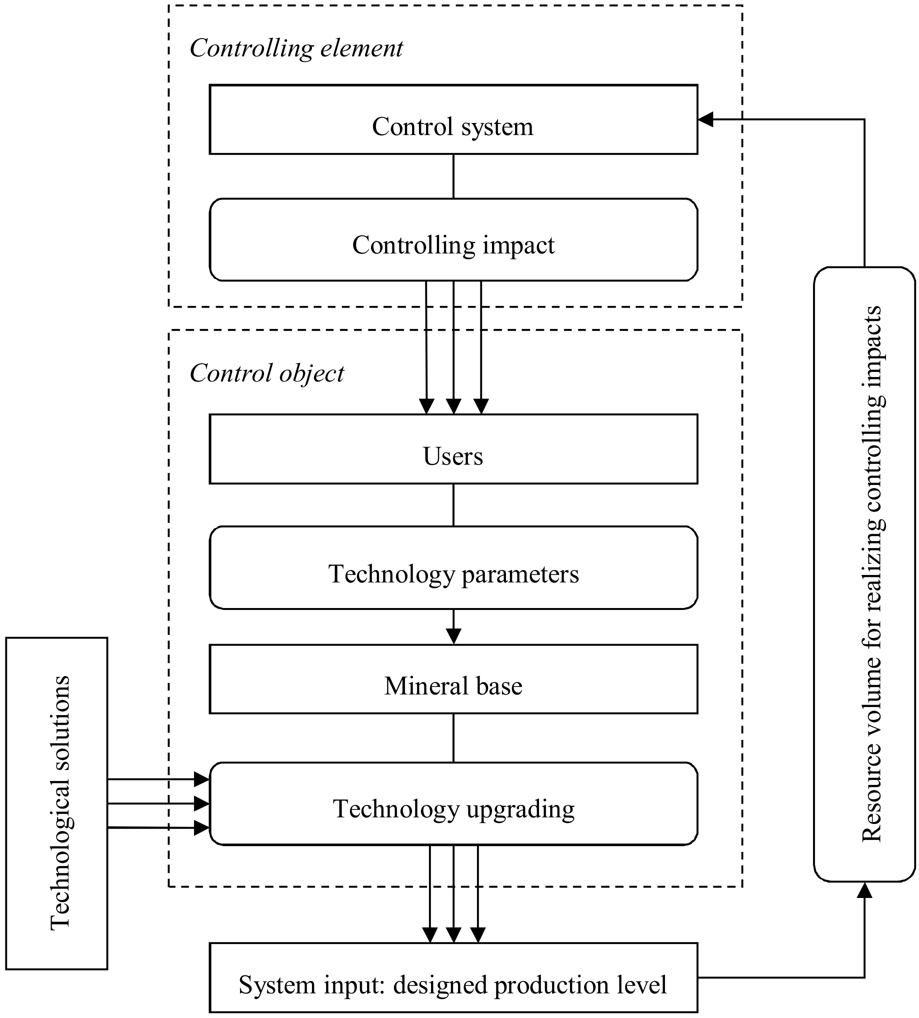

Fig. 3. Structural and functional scheme of system controlling a mining enterprise

The programme provides graphic interpretation of calculating schemes. The information body generates controlling impacts on the controlled object. The ratio between the impacts of the controlling centre and the controlled object conditions is determined by the transition function of the considered system.

New process parameters applied are used as controlling impacts. The controlled object's internal states are characterized by possible volumes of the design errors and the system output is the level of mining operations efficiency.

The design sections contain the following data: a mining system, the number of stopes and their sizes, a size limit, oversize yield, the type of drilling machines, the borehole diameter, applied explosives, loading equipment, the volume of the mined rock mass and the quality of raw materials.

In evaluating the quality of mining operations one determines the list of controlled parameters. The divergences of the parameters from their designed values are regulated. The acceptance order of the performed operations and the order of control performance of their correction are considered.

The system controlling mining processes include mathematical models and ways of their optimization. The created system tool is the GIS Arc View characterized by wide possibilities in working with databases and greater efficiency.

The suggested programme is realized at Bosniyskoye dolomite deposit (Russia, The Republic of North Ossetia-Alania).

The deposit reserves make 238mln t, which is sufficient for the open pit functioning with the annual capacity of 700 thousand t for 350 years. The lower part of the Central site of the deposit between 980m and 1090m is mined by benching in three steps (45m, 50m, 15m) bottom up with the slope angles of 70°.

The ore was broken by chamber explosive charges in 1.6m x 2.0m adits of 40m to 50m long. The distance between adits along the strike is 40m-50m. Dolomites roll down the lower bench slope.

Blasting control at Bosniyskoie deposit allowed decreasing the explosive charge quantity by 17% in ore breaking by 50m x 50m x 50m blocks. Blasting indices in ore haulage by blasting are reduced by 10% as compared with the basic technology of powder blast stoping.

The investigated control system connections and regularities allowed formulating interconnections of a designed object, users and an exploitation object in a mathematical form. The system controlling risks is analyzed and synthesized. There was suggested a model of the controlling system aimed at increasing mineral breaking efficiency and the transition and output functions of the system are developed.

The programme implementation of the computer system of the error risk control in drilling and blasting designing includes mathematical models of the considered processes and is aimed at decreasing the technology risk under limited resource conditions and providing a solution making support.

The software system should meet the following requirements:

the possibility of simultaneous application both by users and an administrator;

modern technologies application based on geoinformation systems;

increased efficiency due to a more complete application of computer resources;

availability of a mechanism for transforming data formats for data exchange.

Recommendations for implementing the methods include:

consideration of possible orientation of blasting blocks in borehole drilling;

focus of explosion stresses on maximum values in large-scale blocks;

application of low TNT explosives combined with powerful priming explosives.

Besides the economic efficiency, the quality increase of mining technology designing is characterized by the decreased negative effect on the environment [19-20].

Evaluation of the design conformity with the environment conditions is an integral part of the design (Fig. 4).

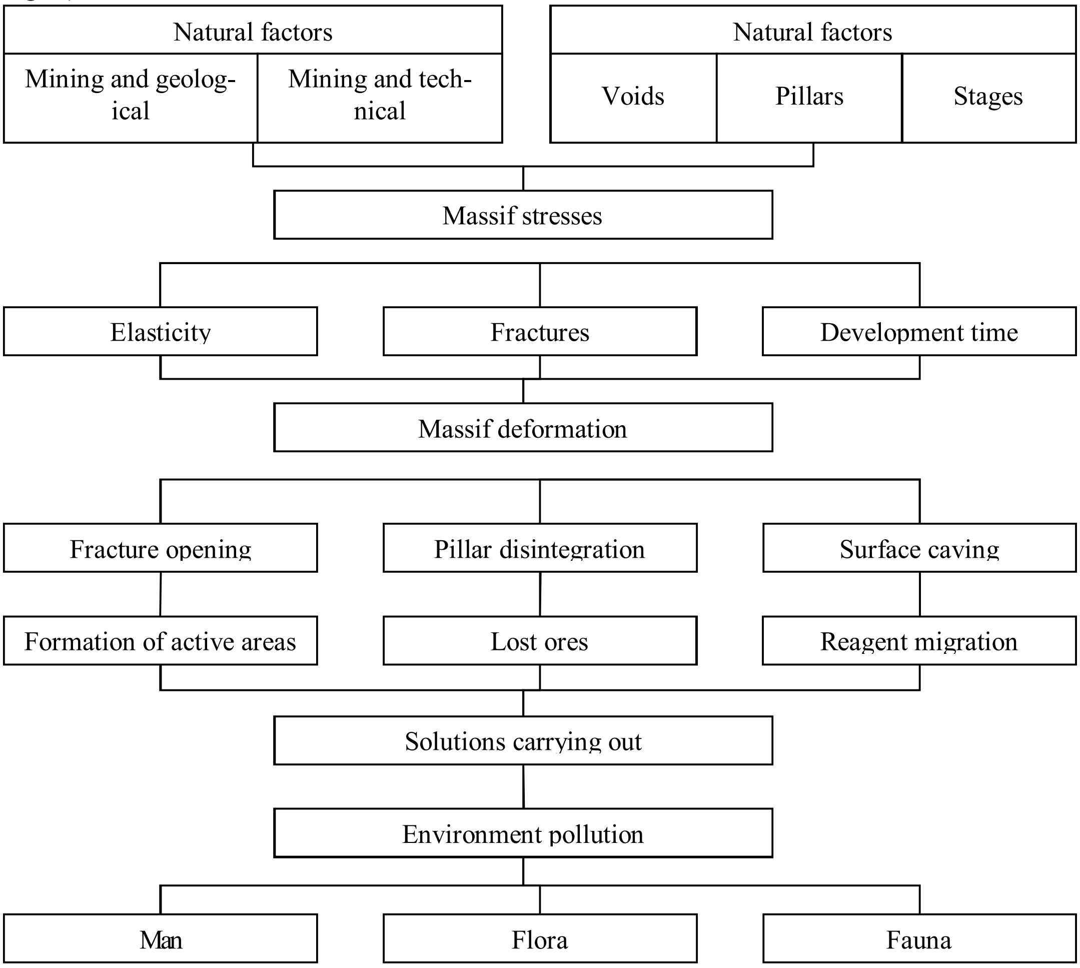

Fig.4. Algorithm of environment evaluation

Conclusions. Implementation of modern designing technologies of mining processes based on concepts of databases in simulation, expert and geoinformation systems of ore mining and processing is a promising, yet not widely used potential for increasing mining efficiency.

The investigated control system connections and regularities allow formulating the principles of interconnections of a designed object, users and an exploitation object on the basis of analyzing and synthesizing the system controlling the design risks as well as developing control models system aimed at increasing mining efficiency.

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SAFE OPERATION OF SURFACE OBJECTS

Purpose. Development of a system analysis of current risks of possible structural design defects and organizational reasons for accident as one of the methods for assessing the reliability of structural elements in the mine surface objects that allows to control over operation safety.

Methodology. An analytical model for determining the risk assessment of a construction accident with collapse of