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Automated Safety Control System and Monitoring of Dangerous Geodynamic Trends in Mining

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ABSTRACT

The concept of the creation for mining-information automated system is proposed to prevent technogenic mountain impacts and alerts about hazardous geodynamic trends. The core of the system is a permanent mathematico-cartographic model for assessing the risk zones and forecasting the impact hazard. The model lives and develops on the basis of current monitoring data of the rocks stress strain state and dangerous geodynamic trends in the breed massif. The object of the system is a natural-technogenic complex in which mining enterprises provide their safety in accordance with federal norms and rules, and the system center monitors an array outside of their competence zones and stimulates an increase in the level of security of the enterprises in information, expert-consultation and technically plane. Service for warning about hazardous geodynamic phenomena prepares the recommendations to improving level of safety of enterprises and warning about the occurrence of man-made or natural emergencies. The Service, created on the early stages the development, continues to work constantly.

Keywords*: Rock burst, stress strain state monitoring, geodynamic dangerous phenomena, mathematico-cartographic modeling*

INTRODUCTION

The Industrial Safety Management of Mining Enterprises at the Federal level regulates the "Regulation on the safe conduct of mining operations in deposits prone to and dangerous to rock impacts" [1], approved by order of Rostekhnadzor dated 02.12.2013 No. 576 and registered in the Ministry of Justice of Russia in 2014. The Regulation establishes mandatory requirements for the safe conduct of mining operations (with the exception of some types of mineral extraction carried out by an open method without the use of explosives). In the Regulation, approved and registered in 2014, there is no mention of the terms: "information technologies" and "computer models"; "automation" and "robotization". This work is aimed at the strict implementation of Federal norms and requirements [1] with the responsible use of modern geoinformation technologies and computer models for geodynamic zoning of the subsoil according to the method [2]. At the same time, a targeted increase in the level of safety of mining enterprises (Enterprises) is provided due to the introduction of automatic measuring devices and methods of calculating the stress-strain-state (SSS) of rocks [3], means of automation and robotization of Enterprises [4].

The object of the study is a changing natural and man-made mining ore complex. The scientific goal of the research is aimed at replenishing the system of knowledge about the patterns and methods of development and preservation of the Earth's interior. The production and technical goal is to develop and implement an automated safety management system and monitoring of dangerous geodynamic trends (ASUiM) on the territory of the Kursk Magnetic Anomaly (KMA). **The main (ultimate) goal** of ASUiM functioning is to preserve the miner's life and reduce economic costs losses even in the case of dangerous dynamic phenomena, prevented man-made mountain shocks and prepared in advance for mountain-tectonic shocks, which we cannot avoid powerful.

The purpose of the work is the substantiation of perspectives and the concept of the creation of ASUiM.

Research tasks. In order to fulfill the purpose of the work, it is necessary to solve three tasks: to choose a research methodology (1), to justify the prospects for the creation of ASUiM (2) and to determine the main provisions of the functioning of the system (3).

1. RESEARCH METHODOLOGY

Forecasting mountain shocks belongs to the class of problems that cannot be solved (difficult to solve) by mathematical methods. For such tasks, a fundamentally new approach should be used mathematico-cartographic modeling (MC-modelling), which organically combines mathematical calculations with cartographic transformations [5]. The universal full-function GIS software system ArcView/ArcGIS (produced by ESRI.com, CA, USA) with spatial analysis modules Spatial Analyst and Geostatistical Analyst is best suited for solving the problems of risk zone estimation on the Earth's surface. The tasks of technological management of enterprises and assessment of the state of the massif of rock are best suited to the specialized one losses even in the case of dangerous dynamic phenomena, prevented man-made mountain shocks and prepared in advance for mountain-tectonic shocks, which we cannot avoid GIS MAINFRAME (produced by the GOI of Scientific Research Center of the Russian Academy of Sciences, Apatite, Russia) and innovative approach to using this system proposed in work [6]. MAINFRAME transmits data on the geometry of subsoil objects (cartographic model) [7] to SIGMA GT, where VAT (mathematical part of the model) is calculated [8], and the results are returned to MAINFRAME [7] and are used when working out issues of design and planning of mining operations with taking into account safety. MAINFRAME is currently the only system in the world among known mining and geological information systems (Datamine, Micromine, etc.), which is able to combine technological management with safety issues of mining operations. The task is to connect ArcGIS – the universal tool for solving environmental and mountain safety problems on the surface of the Earth - with a mainframe that can take into account the array of rocks and is promising for solving safety problems in the conditions of the risk of mountain shocks.

The core of the system is a constantly operating mathematico-cartographic model for assessing risk zones and predicting impact hazards (hereinafter, MC-model). It lives and develops on the basis of current monitoring data of the SSS of rocks and the detection of dangerous geodynamic trends in the rock massif. The main task of the MK model is the geodynamic zoning of the massif and the determination of high-risk zones on it. The suitability of the developed MC-models should be checked by the RR criterion, which has a strictly justified limit (RR=1), which allows to separate the models suitable for forecasting from those unsuitable (with RR>1) and subject to selection [9].

Methodical instructions [2] define the following sequence of works on geodynamic zoning of the deposit: identification of the block structure of the mountain massif, establishment of dynamic interaction of the blocks, transfer of the boundaries of tectonic blocks into mining, selection of tectonically stressed and unloaded zones in the mountain massif, establishment of the stressed state of the intact rock massif taking into account its block structure and the dynamics of the interaction of blocks, the prevention of mountain shocks based on the study of the geodynamics of deposits.

2. PROSPECTS FOR THE CREATION OF ASUIM

The work is directed to the creation of an automated system of safety management and monitoring of dangerous geodynamic phenomena on the territory of the KMA as a whole, outside the territory of enterprises that extract ore within the limits of their mining concessions. This system is abbreviated as ASUiM. It should track the opportunity movements of block structures and the occurrence of rock-tectonic shocks throughout the territory of the KMA and warn about this enterprises falling into the risk zone. This ASUiM should also "manage", that is, ensure an increase in the level of safety of enterprises close to the risk zones of mountain-tectonic shocks, for example, due to the robotization of the most dangerous mining processes and complex automation of the measurement of parameters necessary for the calculation of the stress-strain state (SSS) of rocks in workings, working without a person, automatic control stations of ACS of SSS.

The development of ASUiM should include the following tasks:

1. Develop the digital MC-model of geodynamic processes on the territory of the Kursk Magnetic Anomaly (KMA);
2. Create a monitoring network for stress-strain state (SSS) rock massifs;
3. To organize warning services about dangerous geodynamic phenomena and preparation of recommendations to increase the level of safety of the

main mining enterprises of KMA (hereinafter, Enterprises) and notification of emergencies.

Work plan

Stage 1 (2020)
Development of a cartographic model of the KMA (with layers: topography, tectonics, paleo- and modern geology); determination of requirements for reference points of the regional network of geodynamic monitoring.
Identification of possible risk zones for the occurrence of extraordinary mountain landslides.
Elaboration of primary monitoring program for the regional network.
Estimation of initial values for SSS=parameters in rock massifs on the KMA given territory (according to the results observed in 2020 on the regional network).
Development of recommendations for enterprises to increase their security level (based on the results of the initial assessment of SSS parameters).

Stage 2 (2021)
Creation of the regional and primary local centers for geodynamic trends monitoring.
Assessment of the SSS-parameters, modern geodynamics trends and dangerous man-made objects.
Creating first geodynamic MC-model for techno-natural systems.
Development of recommendations for enterprises to increase the level of their safety (based on the results of the MC-model analysis.

Stage 3 (2022)
Audit of the geodynamic MC-model of techno-natural systems on the given territory processes in the KMA.
Selection of possible risk zones for the occurrence of extraordinary and dangerous movements of rocks and man-made objects;
Development of an automated system for monitoring dangerous geodynamics movements of block structures and the occurrence rock-tectonic shocks throughout the KMA territory;
Creation of the Decision-Making Center (DM-center) of ASUiM and notification Services on dangerous geodynamic processes. Their goals are to increase the level of security of enterprises and take emergency measures in the event of the occurrence (threat of occurrence) of man-made or natural emergencies.

Stage 4 (2023)
Audit of the geodynamic MC-model of techno-natural systems on the given territory KMA;
Identification of possible risk zones for the appearance of extraordinary moving and dangerous man-made objects;
Development of automatic monitoring stations of dangerous geodynamic processes for underground mining;
Development of automatic monitoring stations of dangerous geodynamic processes for open mining.

Stage 5. (2024)
Experimental operation of the system;
Elimination of identified defects;
Determination of the final monitoring program;
Acceptance tests and signing of documents on acceptance of ASUiM into operation.

3. THE MAIN PROVISIONS OF THE SYSTEM'S FUNCTIONING

The service for warning about hazardous geodynamic phenomena, preparing recommendations for improving the level of safety of enterprises and warning about the occurrence (threat of occurrence) of man-made or natural emergencies (the Service) is created at the early stages of the development of an automated control system and continues to work constantly.

The current powers of the Service include:
Participation in research on the problem of assessing risk zones and signaling the danger of rock-tectonic shocks;
Participation in research on the problem of forecasting and preventing rock bursts;
Implementation of interaction with State services for monitoring dangerous geodynamic phenomena, mining enterprises and experts;
Maintaining documentation on issues of rock bumps;
Participation in the development of long-term plans for the development of mining operations, projects for stripping, preparation and development of new deposits;
Summarizing the accumulated experience in the prevention of rock bursts of the KMA;
Collection of information about rock bursts in Russia (causes and reasons for the occurrence, development and completion of the phenomenon, the activities of services, the results of the investigation), analysis of information and conclusions to improve the efficiency of automated control systems.

Principles of interaction between the Service and Enterprises
About dangerous phenomena within their competence, the Enterprises report to the ASUiM Service, and about

dangerous phenomena that occur on the territory of the KMA outside the competence areas of the Enterprises, the Service informs the Enterprises.

The ASUiM Decision Making Center creates and updates a list of experts who are involved in assessing the situation and developing recommendations to prevent rock bursts in difficult situations related to choosing the best solution from alternative.

4. CONCLUSION

1. Mathematical-cartographic modeling, unlike only mathematical modeling, allows finding a solution to the problem of risk assessment, which is accepted by the supervisory authorities, as was shown in [5].

2. Taking into account the fundamental novelty of the proposed mining information system ASUiM, one should treat the stages and terms of creating the system as a perspective, and not as a technical plan that is subject to mandatory implementation.

3. The suitability of the developed models is recommended to be checked by the RR criterion [9], for which the boundary RR=1 is proved, dividing the models into suitable and unsuitable. Model culling according to the condition RR>1 is recommended for all mathematical models in various subject areas. In the area of emergency preparedness, such culling should be considered mandatory.

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