Improvement of technical and methodical means of local control burst- hazard of rock mass

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Abstract. At a number of ore deposits of the Far East and the Kola Peninsula dangerous for mining impacts, measurements of acoustic emission parameters have been carried out and new data have been obtained on the specific features of the manifestation of dangerous forms of rock pressure in various sections of the mine field. A method for measuring the local control device “Prognoz L” has been developed and additional criteria for the impact hazard of an array of rocks from a number of deposits developed by the underground method have been substantiated.

1 Introduction

Reliable and timely information about the geomechanical state of the rock mass, which can be obtained, including using geophysical methods and measurement tools [1], of which the most widely used microseismic (seismoacoustic)and geoacoustic methods. Using the latter, depending on the technical means used, it is possible to carry out both local and regional monitoring of the state of the rock mass. It is based on the experimentally observed and theoretically studied phenomenon of acoustic emission (AE), which accompanies the process of mechanical loading and destruction of rocks [2].

The “Prognoz-L” local impact hazard control device developed at the Mining institute FEB RAS [5], which allows not only recording a large number of AE parameters, but also processing and detailed analysis of the information received, is a tool that has established itself as a means of operational geomechanical control of the edge parts of the array rocks.

The device is successfully operated in the conditions of the underground mines Nikolayevsky, Yuzhny and Silinsky (GMK Dalpolimetall JSC), Aikhal and International mines of Alrosa, Glubokiy PJSC (PIMCA), as well as United Kirovsky and Rasvumchorr mines (JSC Apatite)

2 Methods and results of the research

The portable device for local monitoring of burst hard "Prognoz L" consists of two main parts (fig. 1 a): primary receiving converter (sensor) and measurement unit. Accelerometer

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AP99-1000 series (GlobalTest, Sarov) (fig. 1 b) was chosen as primary receiving converter for the Prognoz L device by results of the detailed analysis, laboratory and field test.

Observed data and stories of operation of the device is stored on micro-SD flash card. The interface of exchange with cards of this format is realized by STM32F405 microcontroller in the form of the hardware module which allows to read out and record data without using a computing core of the microcontroller.

a *b*

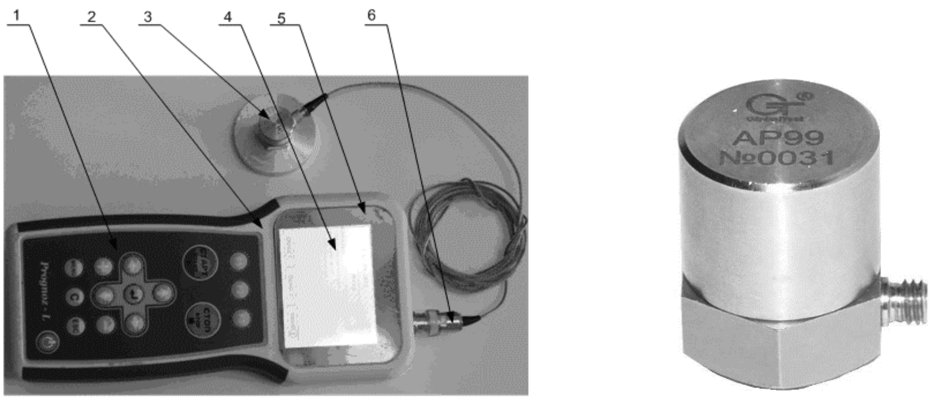

Fig 1. Prognoz L device: a − measurement unit; b − AP99-1000 accelerometer 1 − keyboard; 2 − device housing; 3 − portable sensor (accelerometer); 4 − liquid-crystal display; 5 − polycarbonate protective glass; 6 − socket connection of the portable sensor

There are four modes of the device. Fist is measurement mode. Second mode is monitoring one; the user and engineering menu are used for the setting of the Prognoz L device.

Setting of the device is performed before the measurement of the AE parameters. Adjusted parameters are date, time, record to digital storage device, volume of sound. There is a possibility of adjustment of frequencies, amplitude and time filter of detection of AE of impulses. User and engineering menu are used for this purpose.

A number of algorithms for selection of the useful AE signals and filtration of technological interference of various nature is realized in the device of local monitoring.

For assessment of a condition of the massif the device of local monitoring "Prognoz-L" uses the following criteria: intensity of AE without visible influence of technological processes $\boldsymbol{N_{AE}}$ and an indicator $\boldsymbol{b}$ (amplitude distribution) [6]. The $\boldsymbol{N_{AE}}$ index of intensity allows to assess the achievement of the ultimate loads in the edge of regional part of rock massif. The index $\boldsymbol{b}$ characterizes the instability of process of deformation, increase of quantity of high energy impulses and is calculated by a formula:

$$b = \lg \frac{N^1_{AЭ}}{N^2_{AЭ}} / \lg \frac{A_2}{A_1}, \qquad (1)$$

where **b** – a ratio of number of acoustic impulses with a different amplitude (energy);
A_1 and A_2 – thresholds (levels of sensitivity of the device);
N^1_{AE} and N^2_{AE} – intensity of AE at various thresholds.

Optional AE parameters (spectral characteristics of AE of signals) are used besides the specified criteria (N_{AE} and b) for the assessment of a condition of the massif.

During the operation of the device by the mining enterprises, our institute obtains actual data of measurements taken in the workings of operating mines with signs of the presence of rock pressure. In the course of data processing, shock hazard criteria are regularly adjusted, which depend on parameters that take into account the properties of rocks capable of accumulating potential energy and releasing it in the form of brittle, avalanche-like destruction.

The local control device “Prognoz L” implements a number of algorithms that provide identification of pulses of natural acoustic emission against the background of man-made noise. Natural acoustic emission pulses have a list of signal characteristics compared to background man-made signals, which allows for flexible selection of the instrument at the hardware level.

For the detection of AE pulses, the MARSE parameter (measured area under the signal plot), which is a distant analogue of the energy of an acoustic emission pulse, is used as an identification criterion. The MARSE parameter is simultaneously sensitive to both amplitude and signal duration, which increases the reliability of acoustic impulse identification.

The calculation of the MARSE parameter at time ti (the value on quantum i) is performed in the previous time window of a fixed length Y using the formula:

$$S_i = \sum_{i=1-Y}^{i} A_i \qquad (2)$$

where ***Si*** is the calculated signal area within the current MARSE time window;
Ai - discrete value of the signal amplitude within the current time window.

The registration of the next pulse occurs when the parameter Si exceeds the threshold value of level Sth. At the same time, at all stages of the operation of the identification algorithm, an adaptive adjustment of Spor takes place in accordance with the change of the peak factor of the generalized signal-signal “signal + noise”.

$$S_{nop,i} = A + B \cdot \sum_{j=i-Y}^{j} S_j \qquad (3)$$

where $S_{nop\ I}$ – adaptive threshold change function;
S_j – the value of the MARSE parameter on the j-th sample; A, B - coefficients (tuning parameters), determined empirically, and allowing to adjust the sensitivity of the AE signal detection process;
Y – calculation window length.

The algorithm makes it possible to effectively emit pulses of natural acoustic emission against the background of frequently repeated noise, and provide effective geoacoustic control of the state of the rock mass in conditions of intense man-made noise (man-made noise).

The multi-stage process of brittle fracture of rocks in many cases does not allow one to reliably estimate the degree of impact hazard using criteria that take into account only a quantitative assessment and the ratio of AE impulses of various energies. In the case of transition from a stage of relatively stable accumulation of energy to the stage of germination of a “trunk” crack between micro-fractures [3-4], the probability of an increase in the degree of impact hazard increases even with a low quantitative indicator. In other words, when measuring the shock hazard category of the marginal part of the array, the total energy coefficient of the recorded AE impulses per unit time should be taken into account.

The efficiency of assessing the category of impact hazard of openings with the help of a local device limits the possibility of locating pulses of natural AE, and the values of their energy, due to the use of only one primary converter. Thus, the MARSE parameter can be used as an additional criterion for the geomechanical state of the array, the principle of which is described above.

3 Processing of measurement results

Table 1 shows the measurement data of the AE parameters at the Zvezdniy site of the United Kirov mine, on the horizon + 150m, Avtouklon 170/10, Yukspor, Figure 2, the location of measurement with a local device is indicated by a black dot.

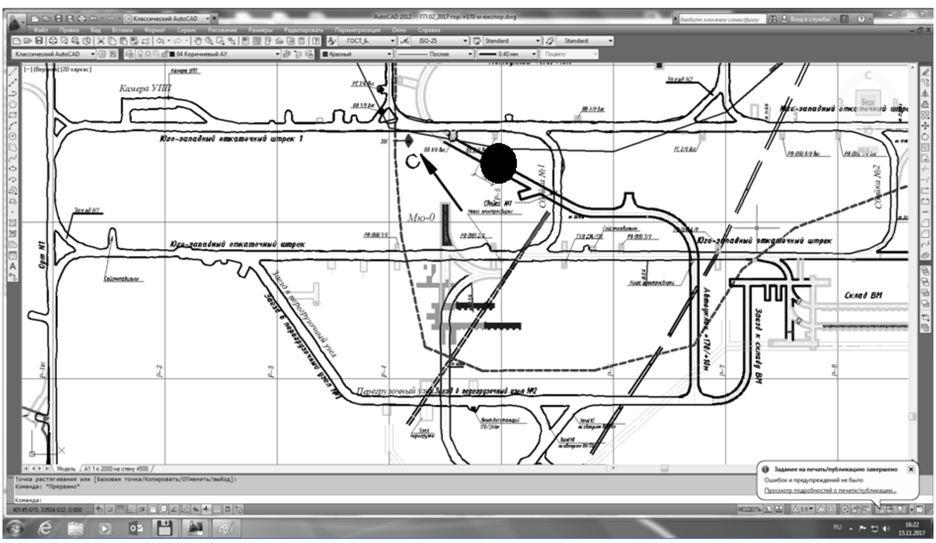

Fig. 2. Local measurement location at the Yukspor mine, Horizon + 150m, Autotilt 170/10, (November 17.21, 2017)

Table 1 Results of measuring AE parameters at the Yukspor mine, Horizon + 150m, Autotilt 170/10

№	Date, Time	t, min.	Threshold, dB		Number of pulses per channel		Average activity N_{15}	Total the energy coefficient, units	Category bursthazard
			1	2	N_1	N_2			
1	17.11.17(11:11)	10	25	33	682	338	17,04	249499923	DANGEROUSLY
2	17.11.17(11:29)	10	25	33	576	227	14,4	148074464	DANGEROUSLY
3	21.11.17(10:55)	10	25	33	114	45	2,85	23271157	NOT DANGEROUS
4	21.11.17(11:05)	10	25	33	107	46	2,67	22487922	NOT DANGEROUS

The degree of impact of this area from November 16 to 23, 2017, was confirmed by SPGU employees by assessing the state of disturbance of wells drilled in the cross to the main current voltage (vertically into the roof), as well as by the method of expert assessments of visual observations. During measurements on November 17, the instrument recorded the DANGER category and the quantitative indicator exceeded the maximum by criterion 3 times. Then, after measures were taken to reduce the effect of voltage on the edge parts of the array, in the form of drilling relief wells, the activity of AE on November 21 was significantly reduced, but the category of this section remained at the same level as DANGERING. This is confirmed by the formation of new cracks in the separation of the roof of this area, the “shooting off” of a lamellar-shaped rock and an increased pinning.

Thus, we can assume that when the stage of the destruction of the massif passes into the stage of formation of relatively larger cracks and merge them into clusters, the quantitative indicator can decrease with a higher degree of probability of a geodynamic event. For this purpose, there is a need to introduce an additional criterion based on the total value of the energy coefficient of AE pulses calculated per unit time. For the host rock conditions of the Yuksporsky field, this indicator is 550,000 over a 15 second interval.

Also in the development of the mine Nicholas, when penetrating the slope of the North 4, mountains. -420 ÷ -406 meters, the device was recorded increased acoustic activity as well as an intense stabbing in rhyolite tuffs and tuff breccias was observed. These rocks are classified as fissured, medium resistance with blocky separation. The coefficient of the fortress on Protodyakonov 12-14. The geodynamic activity of the study area lasted more than 10 days from April 18, 2017. Table 2 shows the data on measurements by a local device in the period of increased acoustic activity of the Northern 4 slope.

Table 2. The results of measuring the AE parameters at the Nikolaevsky mine, North slope 4, mountains. -420 ÷ -406 meters

№	Date, Time	t, min.	Threshold, dB		Number of pulses per channel		Average activity N_{15}	Total the energy coefficient, units	Category bursthazard
			1	2	N_1	N_2			
1	18.04.17 (10:13)	5	10	19	155	138	8,15	8862057	DANGEROUSLY
2	18.04.17(10:21)	5	10	19	291	194	15,31	8285022	DANGEROUSLY
3	21.04.17(10:28)	5	10	19	301	248	15,84	7461657	DANGEROUSLY
4	18.04.17(10:50)	5	10	19	432	409	22,73	28703698	DANGEROUSLY
5	18.04.17(10:55)	5	10	19	895	879	47,10	122080283	DANGEROUSLY
6	18.04.17(11:01)	5	10	19	698	662	22,73	49515662	DANGEROUSLY
7	19.04.17(10:48)	10	10	19	336	287	8,84	16400769	DANGEROUSLY
8	19.04.17(11:00)	10	10	19	578	520	15,62	33033287	DANGEROUSLY
9	19.04.17(11:11)	10	10	19	537	469	14,51	26736665	DANGEROUSLY
10	19.04.17(11:23)	10	10	19	548	462	14,81	26661562	DANGEROUSLY
11	19.04.17(11:33)	10	10	19	245	209	6,62	7886213	DANGEROUSLY
12	19.04.17(11:46)	10	10	19	345	126	9,32	33261050	DANGEROUSLY
13	25.04.17(09:44)	10	10	19	117	111	2,92	9955762	NOT DANGEROUS
14	25.04.17(09:54)	10	10	19	114	109	2,85	8309991	NOT DANGEROUS
15	25.04.17(10:04)	10	10	19	112	110	2,80	6605564	NOT DANGEROUS
16	02.05.17(09:49)	10	10	19	133	129	3,32	18540190	NOT DANGEROUS

Also, the degree of impact of this area from April 18 to May 2, 2017, was confirmed by the existing automated system of rock pressure control ASKGD (Prognoz-ADS), which formed the acoustically active zone for a given period of time. Also in the workings on the roof and sides there were signs of increased rock pressure. For the conditions of the host rocks of tuffs and tuffs of breezing rhyolites from the Nikolaevskoye deposit, the total MARSE is 175,000 over a 15-second interval.

4 Conclusions

In the conditions of the operating mines, a geoacoustic portable device for local impact control “Prognoz L” was put into operation, which allows recording and determining AE parameters even in the presence of technological noise.

Successfully conducted work on the study of the impact of a local device in conjunction with an automated system for monitoring the rock pressure of the ASKGD.

Efficient algorithms and software have been developed for operation of the device, which ensure registration of existing AE mines of signals in mine conditions, determination of their parameters (intensity of acoustic emission; main frequency of AE pulses; duration, amplitude and relative energy characteristic of AE events, etc.) geomechanical control results. The work on the analysis of the total energy coefficient of pulses of AE. According to the results of the analysis, preliminary values of the coefficient Sj were obtained to highlight an additional criterion for the impact hazard of the host rocks of the operating Nikolayevsky mine.

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