Development of multi-channel portable impact control device for local assessment of the state of the edge parts of the rock massif

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Abstract. The improvement directions of geoacoustic methods and software and hardware used for local rock mass impact hazard assessment are proposed in the article, in particular, comparison is made with the successfully proven Prognoz L device. Three main directions for its modernization are proposed, including the improvement of constructive elements, providing for the use of discrete components and wireless technologies advantages, a new approach to software development and the use of a "full" operating system. Thirdly, it is hardware improvement of the local control device, which in the future will provide source-locating possibility of acoustic emission in the massif.

1 Introduction

At the present geoacoustic signal security systems development is becoming more urgent because of mining sites volume increasing and high mining work speed [1, 2]. Such systems belong to non-destructive testing methods and therefore is absence of requirement of the rock mass continuity violation are their main advantage with the ability to large volume control [3]. The entire burden of providing expert assessment of rock mass state falls on smart systems of data processing and interpretation that obtained through passive registration of natural processes caused by mining [4]. This determines the effectiveness of their use in real dynamic production conditions.

The Mining Institute FEB RAS together with the NC Geomechanics St. Petersburg Mining University is developing an approach to shock hazard local control on based of software and hardware systems using geoacoustic methods in connection with task relevance.

1.1 Overview of tools used

Prognoz L is one of the devices of local control of mining pressure, that allows to carry out local control of shock hazard, combining modern technical means and flexible software, and is successfully applied on a number Russian mines.

The following criteria are used to determine the impact hazard degree by analytical software of the local control device: the average acoustic emission signal intensity $N1_{AE}$

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and the amplitude allocation index b. Scientific and practical usage and laboratory tests of the methodological support of the local control device are showed sufficient precisy and valid assessment of the impact hazard category corresponding to the initial destruction moment for strong rocks. From other side, the flexibility of the calculation parameters allows for the adjustment of analytical algorithms taking into account the features of almost any mining enterprise.

It should also be noted that the flexibility of the software provided by device developers allows producing additional methods of analysis and processing of rock mass state monitoring results.

As a result of portable device Prognoz L tests conducted in Kirov mine JSC "PhosAgro" [5]:

– Detailed analysis results of signal wave forms and trends of acoustic emission spectral-energy parameters for a wide range of mountain-geological conditions of rock pressure development are obtained;

– A qualitative model of geoacoustic phenomena in mine areas is formulated;

– The acoustic emission signals classification by spectral composition and their correlator forms is carried out, which determine their belonging to a certain source type;

– The modern algorithm of information flow processing and analysis based on the pattern recognition concept is developed. The algorithm is based on spectral-correlation analysis of random processes [6, 7].

Based on the above, it can be concluded that the developed device has undeniable advantages, including:

– Light weight and compact dimensions, allowing to carry out device transportation and to carry out necessary measurements;

– The presence of a graphical display, allowing with sufficient comfort and acceptable information to adjust built-in software parameters and analyze measurements results, etc.

2 Features of the developed device

More than biennial experience in the Prognoz L operation at various industrial objects allowed us to formulate requirements for the device hardware and software modernization and the development of its extended version, which has a number of advantages.

These requirements can be divided into three groups:

– Construction improvements;

– Software improvements;

– Hardware improvements.

2.1 Constructive features

As a design improvement, it is proposed to abandon the film keyboard as the main method of information input and control of the device. Touch screens are now becoming the most common and convenient to use. The additional keyboard in this case can be only an auxiliary input tool. The keys of this keyboard should be assigned to the most popular control command of the built-in software, as well as the device on and off buttons.

It should also be noted that since the device is supposed to be used in low light conditions, it is proposed to equip an additional keyboard with additional illumination.

Currently, the Prognoz L device uses a built-in battery to provide power supply. To replace the battery, it is necessary to disassemble the device in stationary conditions, which is unacceptable in the conditions of continuous measurement works at industrial objects. It is proposed to develop and implement a power supply system with duplicating of the supply elements with the possibility of operational "hot" replacement of the power elements of the device as a constructive improvement.

It is necessary to provide the device protection from external influences not lower than IP65 because of usage of the device in aggressive climatic environment conditions, in high humidity conditions and dust for most of the time. At the same time, it is should be provided sealed plugs for all external interfaces as a mandatory condition. It should be provided, if possible, wireless technology to increased protection, communicate with external devices and to charge the device's batteries.

A STM32 family microcontroller is the Prognoz l device computational core currently. The used microcontroller does not allow full operating system using and therefore, as a built-in software is used specially developed by the C language programming [8].

High performance of the created systems is advantage of this approach, and main disadvantages are need for hardware reprogramming of each device instance when making changes to control program code and control program development and modernization complexity.

The use of Intel Compute Stick [BLKSTK2m364CC] nettop based on x64 architecture is the most optimal approach in this case.

2.2 Improve the software

It is proposed to use Windows 10 IoT Enterprise - a product of Microsoft, made on the Windows 10 core, as an operating system.

The advantages of this operating system are:

– Intending for use on commercial devices (in accordance with the license agreement): kiosks, ATMs, thin clients, POS-systems, medical systems, information boards, etc.;

– Available in the Long Term Servicing Branch form (LTSB - long term maintenance assembly), which means a complete functional updates rejection that can make unplanned changes to the OS running on a specialized device. Using Windows 10 IoT Enterprise on embedded systems ensures stable and predictable device operation over a long period of time;

– High demand among software developers and users;дружелюбный графический интерфейс;

– Embedding capabilities: device lock, write filters, pop-up notification lock, etc.);

– Extensive software development capabilities using the .NET Framework and .NET Core platforms and embedding many other technologies and software solutions with extensive data display and processing capabilities;

– Support for Enhanced Write Filter (controllable write filter), which allows to protect the device software from viruses, trojans, as well as inexperienced users, limiting access to the file space.

The use of the Windows operating system allows to reduce time and cost of developing specialized software registration, visualization and analysis through application of developed tools to quickly develop software using third-party modules and libraries [9, 10], including as common mathematical analysis packages as MATLAB. This will allow more successful implementation and testing of various algorithms [11, 12].

The use of a full operating system with a developed graphical user interface allows you to equip the updated device with additional software.

As an additional software can be recommended:

– Reference database;
– Graphic image plans for underground horizons of the mining enterprise;
– Software tools for reporting on the results of measurements;

– Automatic extensible database of measurement reports.

2.3 Improve the hardware

Is should be paid to the technical capabilities of analog information input when forming requirements for improving the local control device. Currently, it is possible to process one channel of analog data with a frequency of 100 kHz and a resolution of 16 bits. It is not possibility of locating the source of acoustic emission in the array in this case. The need for a linear location of signals was formulated at the initial device development stage with the possibility of expanding in relation to a flat and three-dimensional location as a result of the practical use of the local control device. Note that the existing technical characteristics of existing local control device hardware do not allow to fulfill these needs.

To solve this problem, it is proposed to use analog-to-digital transformation industrial modules developed by the research and production group R-Technology. As the ADC selected RT USB3000, which is a compact universal 8-channel ADC, connected to a computer via USB 2.0 interface.

The device equipment additionally includes a 2-channel DAC and input/output digital lines.

The device can be used as a multi-channel oscilloscope, spectroanalyzer or logic analyzer, as well as a full-fledged recorder with the ability to save data on the computer's hard disk without breaks and recording time restrictions.

Circuit design of the input stages provides:

– High-precision measurements whatever of the signal source output impedance;
– Possibility to measure high voltage signals directly through resistive dividers;
– Low passage between channels and commutation noise lack;
– High input impedance of all channels in any operating mode.

Small dimensions and weight, as well as the ability to power directly from the USB bus to allow the use of the RT USB3000 in a compact mobile measuring complexes on the base of the laptop, the possibility of simultaneous acquisition, processing, visualization and storage of data without gaps for an unlimited time.

The included software for your computer (OS Windows) allows you to:

– Start working with the device immediately after connection, without prior calibration and programming;
– Process, visualize and save data to your computer's hard drive in real time.

Note that the maximum frequency of digitization is 750 kHz per channel if simultaneous use of four analog-to digital conversion channels, and 375 kHz if eight channels. This significantly exceeds the current local control device's capabilities [13].

The use of four or more channels of analog information input from the acoustic emission receivers will allow further to locate of acoustic emission sources on the plane and in the volume after the development of the corresponding software.

Sensors are selected depending on the measurement modes used in the multi-channel local shock hazard control device and differ in the type of built-in electronics. Recommended types of sensors are shown in the table 1.

Table 1. Recommended sensor types.

Characteristic	GT250	GT350
Type	low frequency with amplifier	broadband with amplifier
The electroacoustic conversion coefficient, dB Rel. 1 W / m / s	> 90	> 75
Operating frequency, kHz	50	120
Bandwidth, kHz	40 ... 100	100 ... 800
Gain	10	10

The primary frequency converters have built-in electronics, therefore, it is should be supplied constant voltage to the output lines simultaneously with reading the analog signal from the sensor output, which will be used to ensure the operation of the built-in electronics. This involves the development of a specialized preamplifier, which combines the sensor's power supply functions and the signal amplifier to ensure the coordination of the levels at the sensor output and the input of the analog-digital conversion module. Also, it is should be provide the possibility of software change of the gain to ensure the widest dynamic range of measurements as a necessary condition of the development of a specialized pre-amplifier. The use of digital outputs of the RT USB3000 analog-to-digital conversion module is preferred to control the amplifier and switch the gain.

There is a block diagram of a multichannel local impact hazard monitoring device at the figure 1.

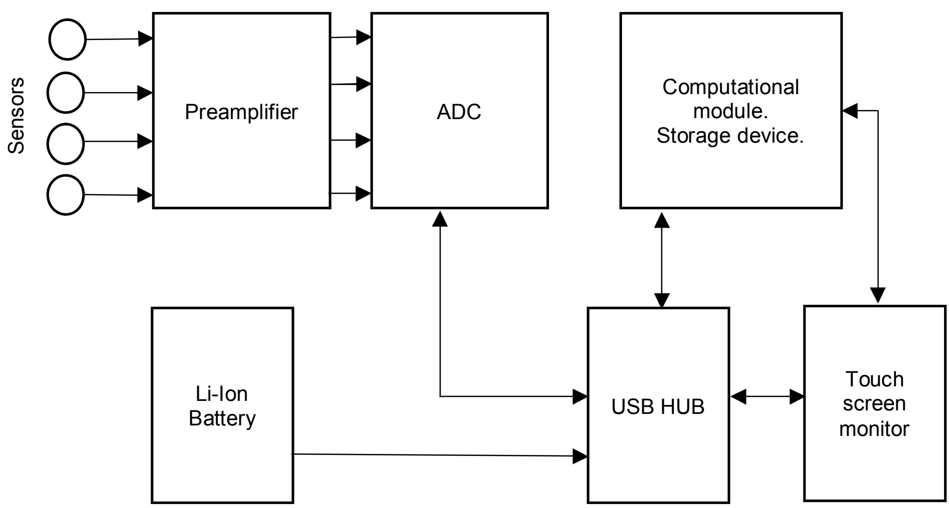

Fig. 1. Block diagram of a multichannel device for local shock hazard control.

3 Conclusion

On the one hand, proposed improving the structural, hardware and software will allow you to obtain a better instrument for local control of impact hazard in the rock massif, giving its users many new functions for use in the field, as well as convenience and comfort during use. On the other hand, such an approach to the development of a portable device will allow its developers to more quickly implement advanced tools aimed at implementing impact hazard local control, correct software errors and improve the technical device characteristics. Thus, the set of proposed tools is an important and necessary step in the geoacoustic tools development of impact hazard local control in the rock mass.

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