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Development of Acoustic Control Method of Mode of Deformation of the Coal Massif in the Process of Underground Mining

A. Shashenko, Y. Maslennikov, A. Solodyankin

A mineral in-depth deposit mining is an actual task for Ukraine. Development of industry calls for intensification of mineral deposits extraction, which growth occurs together with continuously increasing mining depth. With it the effect of rock pressure increases, and the available methods, and means to ensure stability of workings as well as and workers' safety are not very efficient. The task of coal mining in Donbass within horizons being deeper than 1,000 m where its main reserves are concentrated is especially important under the conditions of energy problems.

The tension level in the critical area of formation of stopes and development workings under these complicated mining and geological conditions has such meanings at which together with some other factors rock pressure is often critical, and can show itself as sudden outbursts of coal, rock and gas. They result in deaths of workers, equipment damage, termination of mining and preparation works, etc.

The problem of mineral deposits mining under such complicated conditions is connected with solution of several problems among which the forecast of the gas-dynamic demonstrations of rock pressure is of the greatest importance.

Application of technical means and technological methods to ensure workings stability and safety of work under mining and geological conditions complicated by the presence of multiple tectonic irregularities which are quite difficult to be detected while prospecting results in time waste and finance expenditures, and changes in mining technology and application of the specific safety measures. Finally, it affects the cost of coal mined. Extra expenses connected with the unexpected detection of geological irregularity in the process of working can be significantly reduced if the appropriate geo-mechanical information is available. It stipulates the necessity to have constant information concerning the changes of mining and geological conditions of the massif near the working that is to forecast to be necessary, both from the safety and technical points of view.

The most general approach to solve a problem of the workings stability under conditions of burst risk as well as geological irregularities is to estimate potential energy accumulated in the massif with complicated structure namely in the zone of the increased rock pressure. The main factor under these conditions is the availability of concentration of tensions, distributed in the area of the increased rock tension within limited small field. These tensions practically have such a degree under the conditions of critical ratio of determining parameters when a burst being catastrophic phenomenon is possible. Analytical methods using the elements of linear theory of elasticity for objects being complex from the point of view of the structure and application of load cannot be applied. As for the mathematical methods, they are not developed enough to describe the non-linear systems under consideration. That is why to ensure safe and effective work under such difficult conditions it is extremely important to work out reliable ways of workings stability methods forecast based on the control of the zone of increased tensions parameters in unmined massif area, and its moving character within coalface advance. The acoustic non-destructive control of rock with estimation of frequency parameters of artificially activated signal (working mechanisms noise) is the most acceptable

one. The character of the described phenomenon is local. Stretch of tensions anomalous concentration zone formation does not exceed the dimension of the increased rock tension along strike into the massif depth and is about 30–40 m for Donbass.

Measuring of the mode of deformation (MD) of the rock massif under natural conditions is a complicated task. Today, the two methods of study are available [1]:

- method based on mechanical measurements;
- method based on geophysical methods.

Mechanical methods of MD in rock massif measurements are based on general principles used in mechanics of rigid body: continuity and isotropy of medium, tensions and deformations limitation, etc.

Theoretical and instrumental acoustic base helps to consider these methods as the most important for mining geophysics if only structural irregularities are determined. The difference of methods lies in frequency ranges of fluctuations under consideration. To solve practical problems these methods were used and developed in Moscow State Mining University, Institute of Mining named after A.A. Skochinsky, Institute of the Earth Physics (Russia), Donetsk Coal Institute, the National Mining University (NMU), Institute of Geotechnical Mechanics (Ukraine) and others.

The tendency to use the characteristics of acoustic fluctuations as an informative parameter is the most applicable to solve the problem of prognosis of burst risk zones within coal rock massif because it is possible to consider the fact of interaction of these vibrations energy with potential energy enclosed in the area of their extension as the determined one.

On the one hand acoustic methods are divided into passive methods (registration and analysis of the natural acoustic activity of a massif) and active ones (generation of artificial signals with their further registration and processing), on the other hand they are divided according to the class of problems being solved with their application.

Development of the acoustic trend in the rock massif marginal area condition study at the Department of Construction Geotechnology and Constructions of the NMU started in 1981. They were based on works that had carried out since the beginning of the 60s in the Central acoustic laboratory (Gorlovka, Ukraine). The idea used as a foundation for these works is that acoustic impulses of the natural origin are the presages of the dynamic phenomenon in the working, and the prognosis of sudden outbursts was to record and study their frequency and intensity. But the deeper horizons are developed and the more often bodies transfer from brittle failure to visco-plastic deformation the less reliable the method is.

The method developed at the Department of Construction Geotechnology and Geo-mechanics of the NMU is based on absolutely new approach of active probing of the zone under consideration by the artificial signal namely the noise of mechanisms working in mine [2-5]. Information content of the new method was no more dependent on the natural noisiness of the massif. The result of the spectral analysis of the received signal is the integral estimation of the area under study by means of control of the level of mechanical tensions in it as integrated indicator K . The interaction between the gain-frequency characteristics of elastic vibrations propagating in the massif and the level of tensions occur in it enabled to use this index as an indicator of entering the dangerous zone in the process of current prognosis of coal seams burst risk.

Both the method and equipment had the widest approbation as well industrial testing. Several sets of equipment were produced and successfully exploited in Karaganda, Kuznetsk, Rostov, Donetsk coal basins. High exploitation characteristics of the method as for earliness, reliability, manufacturability to compare with other methods were proved. This confirmed the correctness of the idea put into its foundation.

The successful application of the equipment called AK-1 for the coal massif condition diagnostics enabled to use it for the estimation of rocks condition in the lateral working vicinity. The mine study to check acoustic method of rock massif condition control was carried out in the process of roadheading by the rotor combine «Robbins» during the construction of a derivation tunnel of the Irganajskaja HPS, and in the process of core prognosis holes drilling in mine named after Stakhanov (Ukraine), and mine named after Skochinski (Ukraine) in high-duty as well as burst-risk rocks. Control of the stressed rock massif condition was performed out continuously during the combine and boring rig operations [6].

The study shows that the acoustic control method based on the AK-1 registers the burst-risk zone in a rock within distance to it and continues to do that it at the end of the zone, and at some distance away from it. In this field the method is practically feasible, easy to use, and very reliable, and enables to avoid drilling of test core and exploratory holes. This fact significantly reduces the combine stoppage, ensures safety of work and increases its effectiveness greatly. Thus the acoustic control method developed by the NMU specialists can be applied for the estimation of the rock condition in vicinity of any lateral working.

Another task of the study performed was to consider the possibility of this method application for the automatic control of the combine operation in the process of roadheading in highly tensed rocks. According to the results of the study the system of heading machine automated control with the help of AK-1 was proposed and the corresponding recommendations were given.

The considered spheres of the method and equipment application concerned the highly tensed coal massifs which limits of the parameter K . changes were from 1 to 5 relative units. The critical level of dangerous tensions of me massif corresponded to $K=3$.

Prolonged observations on the basis of the method prove the possibility of registration even if the most insignificant MD changes of area under study within K readings from 0 to 1. take place. The change of the constant mean K level in a "safe" zone from the point of view of sudden bursts of coal and gas was several times observed while entering the zone of small amplitude tectonic irregularities. The successive character of the probing signal source advance together with the working enables to ensure the constant on time scanning of the given area with the aim of detecting the geological irregularities by means of index K changes analysis in the area of its small values. The study took place in "Dobropolskaja" mine (Ukraine) where the crossing of geological irregularities by workings was everywhere.

As a result of the carried out experiments it was determined for the conditions of small-amplitude geological irregularities that the prognostic index K of an acoustic signal in the process of probing the massif in front of the working coalface for sure correlates with the zone of irregularity within $K=0,2-0,8$ [7].

Thus as a result of long period of studies and research by the NMU specialists the method and equipment of acoustic control of the rock massif are created and effectively used. This method and equipment enable

- to detect and inform in advance on the possibility of critical situations occurrence in the process of mining
- on the basis of acoustic measuring to evaluate the condition of burst-risk massif just while working operations (as the results of experiments in mine showed) and take into account non-uniformity of the tensed condition along the working spreading, structural irregularity of the surrounding edge rock massif
- to evaluate the efficiency of blowout measures directly during their realization
- to predict the zones of geological irregularities in front of the working face
- to predict rock bumps in deep mines.

As for the efficiency and reliability the method meets the demands of today concerning control and rock massif prognosis. Taking into account high level of modern electronic means to collect and process the method helps to change to qualitatively new level of approach to the problem of condition estimation rock massif being far away from the working coalface.

Mining enterprises transition to a higher technical level and serious complication of the mining conditions, increase in the working depth, necessity of deposits extraction under complicated mining, geological, technical and geodynamic conditions result in the necessity to automate not only the control of separate operations and mining processes but the whole system in the form of geomechanical monitoring of the underground space.

The safety of the underground personnel is of the greatest importance among the problems being solved with the help of the geomonitoring system. It can be done with the help of continuous control of the degree nonuniformity degree of stress fields occurred within massif. The method and equipment of acoustic control of coal strata burst risk is one of the main modules of the system of rock massif geomonitoring.

As for the future development of the method of acoustic probing and its including into the system of geomechanical monitoring it is necessary to solve several problems:

- development of the wave equation taking into consideration the availability of the initial tension in the area of acoustic vibrations propagation which form would be totally match the real stress condition of the massif
- spectral analysis of the real acoustic signals with the help of which the massif is probed to create the data base to solve the given equation
- creation of the system of the signal received from the massif by means of communication links without significant deformation, archiving of such signals and their transformation into digital form for further processing
- creation of soft ware and hardware of the acoustic signal initial and main processing with the aim of ensuring the main wave equation and algorithm of the signal processing realization
- development of the system of diagnostics of the element of feedback unit in the contour of technological processes regulation.

Acoustic trend of research and study as the part of the system will ensure on the one hand its supplementation with the current information on the real situation and on the other hand will

be continuously supplemented base of initial data for solving the main wave equation to create stress fields maps and distribute nonuniformity within the unmined area of massif.

Acoustic method and equipment used to be independent trend of prognosis of gas and dynamic phenomena in coal mines. Their improvement and wide range of application, and developing software and hardware for signal processing make them basis component of other trend which is in progress at the Department. We mean geomechanical monitoring of underground space of objects [8].

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