Determination of geological conditions of gassy coal seams on the basis of seismic acoustic profiling in underground mine workings

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Abstract: The article views the experience of mine geophysical prospecting using a seismic screening method of roof rocks from mine workings. The possibility of recording coal seams structural disturbances is estimated based on the analysis of seismic signals velocity fluctuation. The results of coal seam conditions assessment and their influence on the technological process of coal mining are presented.

1. Introduction
The current level of scientific and technical support of a coal mining process allows us to use methods of geophysical measurements for the estimation of coal seams roof parameters, on the basis of artificially generated physical fields of various nature: electric, electromagnetic, and seismoacoustic. Any of these investigations is performed, based on a single principle of certain characteristic changes during waves passing through the roof rocks of the extraction panel.

2. Materials
The main factor limiting the use of the listed types of geophysical equipment in mine workings is the increased safety requirements for equipment operated in coal mines, which are met by very few of the measurement systems available on the market. At the same time, the safe manufacturing of geophysical instruments often significantly limits their technical and operational characteristics. For seismoacoustic screening of a coal-rock massif in mine conditions the authors use an autonomous seismic station "R-1" with the following characteristics: number of registration channels - 1; the maximum capacity of a storage device CompactFlash is 16 GB; amplification of the preamplifier, once - 1, 2, 4, 8, 16, 32, 64; the band of recorded frequencies is 0 ÷ 3200 Hz; the sampling interval is 4, 2, 1, 0.5, 0.25, ms; the timing error is less than ± 1 ms/ 8h. The registration of seismic data is programmed using a computer with a USB-host port and an operating system that supports the FAT file system and storage devices of a USB Mass Storage standard. For the estimation of extraction pillars roof conditions in coal mines one can highlight the sampling step among the mentioned characteristics of the seismic stations "R-1". The possibility of setting a sampling step to 0.25 ms significantly increases the accuracy of measurements within the extraction panel boundary. For example, consider the station capabilities with sampling intervals: 2, 1, 0.5 and 0.25 ms (table 1).
Table 1. The possibility of registration, when physico-mechanical parameters of the extraction panel roof fluctuate.

| Interval of velocity change in a coal-rock massif | Sampling step 2 ms | Sampling step 1 ms | Sampling step 0.5 ms | Sampling step 0.25 ms |
|--------------------------------------------------|--------------------|--------------------|----------------------|----------------------|
| 2.8 km/s – 3.2 km/s                              | 44.8 m             | 22.4 m             | 11.2 m               | 5.6 m                |
| 3.2 km/s – 3.6 km/s                              | 57.6 m             | 28.8 m             | 14.4 m               | 7.2 m                |

The Table presents a calculation, showing the minimally recorded length of a rock section with altered physico-mechanical parameters, when performing a seismic screening. Three values of longitudinal seismic waves passing velocity in the roof of the extraction panel are taken into account, resorting to the experience of undertaken mine measurements, characterized as follows: 3.2 km/s - medium-stable condition, average strength parameters, 2.8 km/s - rocks unstable, fissured, 3.6 km/s strong, resistant rocks [1]. Accordingly, in the thickness of the extraction panel medium-stable rocks, when recording data with a sampling step of 0.25 ms, it is possible to fix an unstable, fractured inclusion of a 5.6 m length and a section of strong, stable rocks of a starting 7.2 m length.

3. Methods
The method of research that allows the most use of the autonomous seismic station “P-1” capabilities is a seismic screening [2]. When performing the geophysical works, a certain number of stations with a set interval are linearly distributed across the mine working rim with deepening and installation of a receiving element. Excitation of seismic waves is performed from a parallel mine working with a given step based on the presented schematic diagrams (figure 1).

4. Discussion
Taking into account a minimal interference background possible within the limits of the operating coal mining enterprise, the presented equipment set allows data recording with a maximum travel time length of up to 500 m. Examples of a signal recording in various pickets of oscillation excitation are shown in figure 2. At the same time, two kinds of waves are captured in the roof: longitudinal (a red line) and cross-sectional (a green line) [3].

As the main analyzing parameter for assessing the extraction pillar roof condition, a change of velocity parameters registered between two parallel workings is used [4]:

\[ t = \int_{\mu}^{\Pi} \frac{1}{\nu} \cdot dl \text{.} \] (1)
Figure 1. Schemes of passing waves propagation in the extraction panel body from various pickets of oscillation excitation of (POE) to pickets of oscillation reception of (POR): a) from the first POE; b) from the last POE; c) from the central POE.

Figure 2. Initial multichannel seismograms: a) from the first EP; b) from the last EP; c) from the central EP.
\( t \) – seismic wave passing time;
\( V \) - seismic wave passing velocity;
\( l \) – distance from the source (S) to the receiver (R).

In different sections of the extraction panel, the division into which is performed by digitizing and pixelization on N pixels, taking into account the real coordinates, the given dependence is presented like this:

\[
t_i = \sum_{j=1}^{N} \frac{1}{V_j} d_{ij} \quad (i=1...n),
\]

(2)

\( n \) – number of observations;
\( d_{ij} \) – the distance traveled by the ray i in pixel j.

5. Results

The application of the dependence (2) makes it possible to calculate the velocity model of the extraction panel and build on its basis a horizontal geophysical section of velocity characteristics distribution, where a contrast rise or decrease in seismic velocities illustrates the change in the physico-mechanical parameters of the roof rocks. For example, the geophysical section (figure 3) obtained for one of Kuzbass coal mines conditions is characterized by longitudinal seismic waves passing velocities of 3-3.2 km/s, which corresponds to the immediate roof of the coal seam presented by a medium strength argillite.

**Figure 3.** Fragment of horizontal section with velocity parameters distribution in the extraction panel area.

Within the extraction panel studied area the regions, where seismic waves passing velocity decreases in the massif down to 2.8 km / s are identified: A and C. The presence of such regions in the extraction panel area is explained by the increased fracturing due to the assembly chamber location in vicinity of A region and the pump chamber location within the region C boundary.
Also on the geophysical section, regions with the increased seismic velocities are contrasted: B and B1, which characterize manifestations of the main roof, represented by sandstone rocks in the area of the immediate roof thickness lowering down to 2-3 m.

Based on the analysis of the obtained section, the assessment of total conditions was performed in accordance with the VNIMI classification [8, 9]. Taking into account the distribution of velocity parameters in the study area, a medium-stable immediate roof is predicted. Manifestations of unstable roof may correspond to sections which are the subject of influence by regions A and C. Sections of hard-to-break roof are predicted in regions B-B1.

As part of the presented method development, an approbation use of neural network analysis tools was undertaken to improve interpretation operability of unstable and difficult to break roof sections within the studied sections of the extraction panel [10-12]. For this purpose, the horizontal section of velocity parameters distribution within the extraction panel area was divided into intervals: the sections with the most contrasting manifestations of the unstable immediate roof and the hard-to-break main roof were used for training the neural network; for the remaining intervals, a forecast was made.

As the main material for the estimation of active roof parameters of the coal seam the seismic wave propagation velocities determined within the studied section were used. The possibility of employing the amplitude-frequency characteristics of the detected signal was also evaluated, which demonstrated the low expediency of their application under given conditions of seismic vibrations excitation. Within the presented sample of initial data, the neural network analysis of seismic signal velocity parameters confirmed the primary state forecast for the active roof of the extraction panel. The use of a trained neural network to interpret data recorded within the extraction panel of other mines has shown the need for further expansion of a training sampling.

6. Conclusion
The gained practical results of autonomous seismic recorders application for the roof conditions assessment testify to the rationality of using such equipment for addressing issues related to the geophysical survey of the delineated complex mechanized faces (longwalls) in order to identify abnormal tectonic zones and other roof areas with changed geomechanical characteristics. Together with the data of geological prospecting drilling, the results of seismic screening provide an array of data sufficient for the classification of active roofs required for the geophysical support of the coal mining process.

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