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FEATURES OF SEISMO-ACOUSTIC METHODS OF COAL SEAM FAULTS PREDICTION

Seismic-acoustic method to evaluate type and parameters of faults in mined coal seams was developed in the Institute UkrSRSI, NAS Ukraine. The method is based on the usage of computer-aided systems that allow computing and analyzing parameters of seismic wave fields. Developed criteria to identify faultings with using seismic-acoustic method, which are based on the analysis of signal structure, changes in wave train velocity, frequency and amplitude responses and take into account epigenesis stages and structure of coal-bearing strata allow to reveal anomalies with reliability of up to 80 %.

ОСОБЛИВОСТІ СЕЙСМОАКУСТИЧНИХ МЕТОДІВ ПРОГНОЗУ ПОРУШЕНЬ ВУГІЛЬНИХ ПЛАСТІВ

В УкрНДМІ НАНУ розроблено сейсмоакустичний метод визначення типу і параметрів порушень вугільних пластів, що відпрацьовуються. Метод базується на використанні комп'ютерних систем, що дозволяють робити розрахунок і аналіз параметрів сейсмічних хвильових полів. Розроблені критерії виявлення аномалій сейсмоакустичним методом, які базуються на аналізі структури сигналу, зміни швидкостей хвильових пакетів, частоти й амплітуди і враховують стадію епігенезу та структуру вуглевмісної товщі, дозволяють виявляти аномалії з надійністю до 80%.

ОСОБЕННОСТИ СЕЙСМОАКУСТИЧЕСКИХ МЕТОДОВ ПРОГНОЗА НАРУШЕНИЙ УГОЛЬНЫХ ПЛАСТОВ

В УкрНИМИ НАНУ разработан сейсмоакустический метод определения типа и параметров нарушений отрабатываемых угольных пластов. Метод базируется на использовании компьютерных систем, позволяющих производить расчет и анализ параметров сейсмических волновых полей. Разработанные критерии выявления аномалий сейсмоакустическим методом, которые базируются на анализе структуры сигнала, изменениях скоростей волновых пакетов, частоты и амплитуды и учитывают стадию эпигенеза и структуру углевмещающей толщи, позволяют выявлять аномалии с надежностью до 80%.

INTRODUCTION

Seismic-acoustic method to evaluate type and parameters of faults in mined coal seams was developed in the Institute UkrSRSI, NAS Ukraine. The method is based on usage of computer-aided systems that allow computing and analyzing parameters of seismic wave fields.

In order to select specific procedure and spread, it is necessary to develop *a priori* subsurface physical models and based on their use to carry out a number of operations:

– to evaluate structure and characteristics of seismic records that correspond to the model of fault-free coal-bearing strata (including number of wave trains and their nature, first arrival velocity, velocity of propagation of amplitude peak, amplitude responses, frequency responses) taking into account/without taking into account decay of vibrations in coal-bearing strata;

– to evaluate structure and characteristics of seismic records that correspond to the models of coal-bearing strata with faults with options of impact zone sizes and options of change rate of elastic responses of coal and rocks (from 20 – 30 m and up to 35 – 50% for coals of initial stages of metamorphism to 5 – 10 m and 10 – 20% for coals of late stages of metamorphism, both coefficients for enclosing rocks are 50% of those for coal;

– to identify informative wave trains, to evaluate velocity windows and frequency bands for optimal recording.

ANALYSIS

As a starting point for the analysis one should employ typical for coal beds of the Donets Coal Basin parameters established as a result of research (see the Table).

When conducting field measurements, in contrast to methods of common use [1], generation of seismic waves either in seam floor or seam roof is allowed at a distance of not more than 1 m from its boundary.

TYPICAL STRUCTURES OF SEISMIC RECORDS AND CHARACTERISTICS OF WAVE TRAINS RECORDED AT FREE-LYING COAL BEDS OF THE DONETS COAL BASIN *Table*

Wave train number	Characteristics of *PV* and *SV* polarization wave trines		
	Nature of wave train	Velocity characteristics	Frequency (Hz)
1	Lateral pressure wave	Velocity of first arrival equals velocity of propagation of pressure waves in enclosing rocks	from 40 – 50 to 250
2	Lateral shear wave	Velocity of first arrival equals velocity of propagation of shear waves in enclosing rocks	from 80 to 300 at its initial part to 500 in tail-end
3	Guided wave (if seam thickness is more than 1,5 m)	Velocity of maximum of envelope is 90 % of velocity of shear wave propagation in coal	from 300 and higher

Processing should be carried out in two steps. At the first step one should carry out processing of seismic records obtained at the open channel. The object is to obtain reference values of amplitude, velocity and frequency responses of wave trains of different nature. At the second step one should carry out processing of seismic records obtained at the parts where faults are available. The object is to obtain values of deviations of amplitude, velocity and frequency responses of wave trains from the values obtained at the open channel, to compare them with predictive criteria and to make preliminary conclusion on the type and parameters of the fault. On the basis of the analysis of deviation of frequency, velocity and amplitude responses anomalous zones are located. Deviation by 5% of frequency and velocity responses and deviation by 25 – 30% of amplitude responses from an average value serve as criteria for delineation.

Then, based on the known real values of propagation velocities of seismic waves of different nature one should specify previously used physical models of subsurface b to make recalculation of structure and characteristics of seismic records (including number of wave trains, their nature, first arrival velocity, velocity of propagation of maximum of amplitude, amplitude responses, frequency responses) taking into account decay of vibrations in coal-bearing strata with and without fault. Comparative analysis of the results of recalculation and the results of field measurements is made to refine the type and parameters of the fault. Based on the results of comparative analysis final conclusion on the type and parameters of the fault is made.

As a case study we shall consider survey procedure and the results of determining parameters of faults at the area among the east no. 1 passway, the 1st downcast passway and the 18th belt heading of the seam h_4 at Mospinskaya Mine (state-owned enterprise "Donetskugol").

Thickness of the coal seam is 0,7 – 0,85 m. Immediate roof is represented by siltstone of the thickness of 0,6 – 6,0 m. Above is coal seam h_4^1 represented by two coal benches of the thickness of 0,3 and 0,2 m respectively. They are separated by lumpy siltstone of the thickness of 0,35 m. Sandstone of the thickness of more than 17 m occurs in the seam floor. At the survey area low-amplitude faults of different types and amplitudes are struck by mining. To determine their locations and fault strikes is the main target of geophysical operations.

Calculations have shown that if the distance between seams is less than 3 m, a packet of guided waves was observed that corresponded to a waveguide of complex structure (seams h_4 and h_4^1 + siltstone) with velocities and frequency responses that depend on siltstone thickness. As an illustration Figure 1, *a* shows example of theoretical seismic records obtained for a case when the seam h_4^1 is at the distance of 0,6 m from the seam h_4 (without taking into account any faults). Lateral shear wave is numerated as 1; lateral pressure wave is 2; guided wave generated by waveguide of complex structure is 3. *X*- and *Z*-components of wave field are depicted at once (*X*-axis is selected in the direction from energy source towards geophone, and *Z*-axis is selected transversely to the bedding plane). For better visual perception depicted in color are positive biases for *X*-component whereas negative biases are depicted in color for *Z* component. Typical frequencies of lateral waves are in the frequency band of 100 – 300 Hz with maximum of 120 – 140 Hz for pressure waves and 180 – 200 Hz for shear waves. The estimated peak of the guided wave frequency response at siltstone thickness equal to 0,6 m is at the frequencies near 400 Hz, whereas at siltstone thickness equal to 3,0 m the corresponding frequency is only 250 – 300 Hz.

The results of theoretical analysis [2, 3] indicate that in a number of cases it is desirable to locate energy sources within enclosing rocks in immediate proximity to a coal seam (at a distance up to 1 m). The main contribution to wave field generation will be made by direct wave refracted into the seam and lateral waves. For this reason when making preliminary numerical calculations generation of seismic waves was simulated on the centre of the seam and also on the enclosing rocks at distances of 10 and 60 cm from the boundary with the seam (at distances of 0,5 and 1,0 m from its centre).

After the analysis of informative wave train responses at fault-free sections of the seam, simulation of faults of the type *normal fault* and *overlap fault* with amplitudes from 0,5 to 2,0 m (that corresponds to amplitudes of faults struck by workings at the survey area and at the neighboring areas) was made. The results of calculations have shown that informative parameter for identification of faults was maximum modulus of the amplitude of lateral waves. Presence of both normal fault and overlap fault with amplitudes from 0,5 to 1,0 m results in the decrease in this response by a value of 15 – 25. Faults with amplitudes of 1,0 – 2,0 m lead to the decrease in the amplitude of lateral waves up to 20 – 35%. Further increase in the amplitude of a fault results in attenuation of lateral waves by a value of

40% and more. We failed to obtain such relationships for frequency response of lateral waves. Yet it was determined that presence of any disjunctions lead to displacement of the peak of spectral characteristic by a value of 5 – 20 Hz.

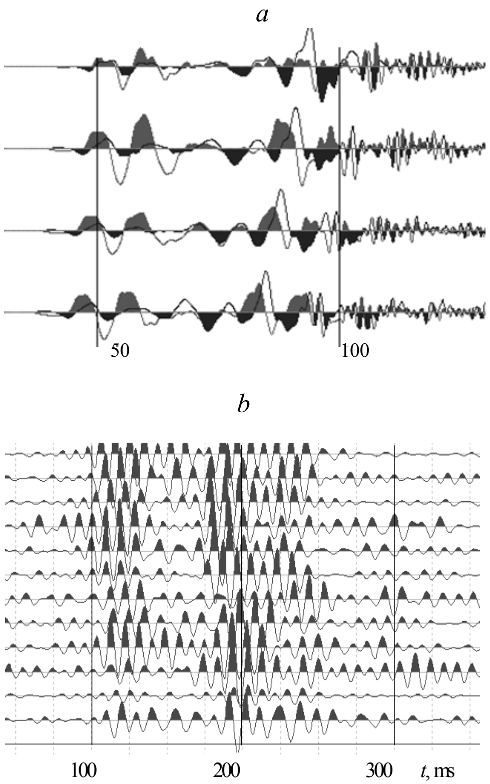

Fig. 1. Examples of theoretical (a) and real (b) seismic records for the seam h₄ at the area of mine field of Mospinskaya Mine planned to be worked out

On the basis of the results of the analysis a conclusion was made on the selection of seismic survey method as a basic method for seismic studies. It was proposed to conduct prospecting in the mode directed to the recording of lateral pressure and shear waves in frequency band of 50 – 250 Hz.

Seismic study was conducted by seismic survey method using 12-channel summing seismic recording system with digital magnetic recording. Profile for generation of seismic waves was located in the east no. 1 passway, 1st south belt heading and 18th belt heading of the seam h_4 (see Fig. 2).

Figure 1, *b* illustrates the set of filtered real seismic records (seismograms) obtained at the seam h_4 at the survey area of mine field. Structures of theoretical and real seismograms are practically adequate that points to the efficiency of the employed modeling methods. While processing data of seismic survey computation of wave field parameters in three velocity windows was made. These velocity windows corresponded (according to data of mathematical modeling) to the record time of lateral pressure and shear waves and also to the guided wave generated by a wave guide of complex structure at the areas where coal seam h_4^1 occurs at small distance (0,5 – 3,0 m) from the seam h_4. In addition, distribution of parameters in the plane of the survey area of the extraction pillar was calculated and anomalous zones were identified (see Fig. 2). In complete conformity with the modelling data the most sensitive parameter in identification of faults is maximum modulus of the amplitude of lateral waves which in anomalous zones decreases by 10 – 15 Hz. It should be mentioned that calculation was made on the basis of the whole of real seismic records irrespective of conditions of generation of seismic waves. Approximately 50% were seismograms obtained while generating seismic vibration field in the seam floor.

As conclusions by the results of the prediction pointed to the presence of the fault stretched from the east no. 1 passway to the no. 18 belt heading, exploring passway was driven from no. 1 south belt heading parallel to no. 1 passway (at the distance of 160 m) which in 25 m has struck a fault with an amplitude of 4,5 m, thus confirming the result of prediction (see Fig. 2). Later on, during development of production section (no. 17 longwall), as extension of exploring passway, no. 17 belt heading was driven and a passway for installing power-operated system was driven too. No. 17 longwall was being mined since 2006. No other faults, as was supposed by the results of the prediction procedure, have been struck during mining of no. 17 longwall.

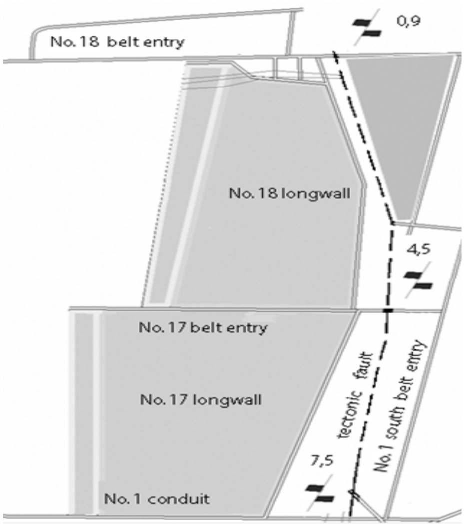

Fig. 2. Lay-out of workings along the seam h_4 (Mospinskaya Mine) driven by the results of seismic-acoustic prediction (generated with the help of geoinformation system GeoMark)

At the next stage, in order to define more exactly location of the fault at a distance of 60 m from no. 17 belt heading, an exploring passway was driven, which in 32 m has struck the fault too. This made possible to define more exactly location of the fault, from no. 17 belt heading to the 18th belt heading. For development of the production section (no. 18 longwall) installation passway was driven, geometry of which was selected in compliance with the results of seismic prediction and the results of driving the exploring passways. After productive development, no. 18 longwall was being mined since 2006. A series of faults located parallel to no. 18 belt heading with amplitude lower than thickness of the seam has been struck during mining.

Thus, preliminary conducted seismic-acoustic experiments employing the above described method have made it possible efficient productive development and mining of no. 17 and 18 longwalls. The results of mining have confirmed completely predicted location of the faults.

CONCLUSIONS

The above method has found its use at the mines of the Donets Coal Basin. Experience of employing the proposed method at more than 30 objects has shown that application of mathematical modeling methods allowed at the stage for preparing to direct observations to determine operating frequency bands and informative velocity windows of the recorded signals. The developed criteria to identify faultings using seismic-acoustic method, which are based on the analysis of signal structure, changes in wave train velocity, frequency and amplitude responses and take into account epigenesis stages and structure of coal-bearing series, can be used for prediction of anomalies with reliability of up to 80%.

REFERENCES

1. А.с. № 4782373/25СССР, ИГП G01V1/00. Способ шахтной пластовой сейсморазведки / А.В. Анциферов, Ю.Г. Мясников, Н.Я. Азаров (Украина). – заявл. 15.10.90; опубл. 17.01.92, Бюл. № 1. – 4 с.

2. Азаров Н.Я. Сейсмоакустический метод прогноза горно-геологических условий эксплуатации угольных месторождений / Н.Я. Азаров, Д.В. Яковлев. – М.: Недра, 1988. – 199 с.

3. Анциферов А.В. Теория и практика шахтной сейсморазведки / А.В. Анциферов. – Донецк: ООО "Алан", 2002. – 312 с.

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