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Advanced Detection Theory and Application Research of Multi-wave and Multi-component Seismic Exploration in Mine

Yunbo Li*[a, b], Hongling Peng[b], Yanqing Wu[a, b]

[a] School of info-Physics and Geologic Engineering, Central South University, Changsha, 410083, P.R.China,
[b] China Coal Science and Industry Group Chongqing Research Institute, Chongqing, 400039, P.R.China.
lyb0112@163.com.

According to the China coal mine geological structure advanced detection demand and need to solve the problems proposed a suitable in coal mine explosion-proof geological detector of multi-wave and multi-component seismic exploration technology, multi-channel data acquisition method in advance, we studied the formation of seismic exploration geological structure interpretation and inference principle, and use the technology and equipment in China's coal mining area of advance geological forecast detection research and application. The research results show that: the development of technology and equipment can accurately predict surrounding rock, rock breaking, and the rich water situation in front of the tunnel face; the max advanced detective range is 145 m.

1. Introduction

At present, there are many deep and complicated working faces in coal mine, which can lead to the occurrence of various mine disasters, which greatly affect the safety of coal mine production. The main advanced detection methods in the field of mine geophysical prospecting in China are: mine geological radar detection technology, advanced detection technology, transient electromagnetic detection technology, etc.. The seismic wave advanced detection is widely used in the tunnel, the method according to fault and subsided column abnormal geological structure and surrounding the contact boundary density and velocity have obvious difference, combined with rock elastic and seismic wave field theory, which has forecast distance, detection effect is good. But in the coal mine is no relevant technology and equipment, the main problem focused on: limited space of whole space communication theory, explosion-proof technology, source problem, detecting instrument, inference and interpretation software etc.. To this end, the authors propose a set of coal mine explosion proof seismic wave geological advanced detection technology, and the use of related technology and equipment to carry out the application research, through the analysis of the results, in order to provide a reference for the long distance geological conditions in coal mine [BAOYU LI and NONG ZHANG (2014), CAI YINGKANG, LIU XIUFENG, SONG ENQIANG (2005), C WRIGHT, E.J WALLS,D DE J. CARNEIRO(2000) reported].

2. The principle of the multi-wave and multi-component seismic advanced detection in the mine

Seismic exploration pinpoints the location of the bad geological body through the acquisition of longitudinal wave and transverse wave data to calculate the coal and rock mechanical parameters. The working principle of multi-wave and multi-component seismic advanced detection uses the three-component reflection seismic method, three component acquisition seismic waves. Seismic exploration is similar to other reflection seismic method, the measuring principle of the echo. Seismic waves produced with a small amount of explosives in the focal point. Seismic wave in the form of spherical wave propagation in the coal and rock, when faced with petrol physical interface (that is, the interface wave impedance difference such as fault, rock fracture zone and collapse column structure), part of the seismic signal reflected, another part of the signal refraction into the front. The reflection of the seismic signal will be geophone receiving high sensitivity. Reflected signals travel

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time and reflection interface is proportional to the distance, so can provide a direct measurement. As shown in figure l.

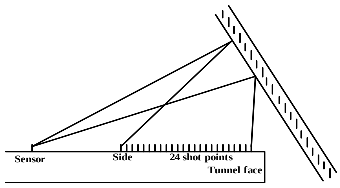

Figure 1: The advanced detection principle diagram of DTC-150

The site layout and test process of DTC - 150 consists of a series of shot point, one or two 3 D receiving sensor (X, Y, Z direction), a receiver and a data processing system. The received signal in the high precision sensors, only the reflected signal from the front of the tunneling surface and side contains the information about the rocks ahead. By the travel time V_P:
Where X_1 is the distance between the blasting hole and sensor; T_1 is the time of direct longitudinal wave.
The distances between reflective surface and sensor, drivage face can be deduced through the measured transmission time of reflection wave and known propagation velocity of seismic wave.

$$T_2 = \frac{X_2 + X_3}{V_p} = \frac{2X_2 + X_1}{V_p} \tag{1}$$

Where T_2 is the transmission time of the reflected wave; X_2 is the distance between the blasting hole and the reflective surface; $X_3$is the distance between the sensor and the reflective surface.
According to the basic theory of seismic exploration, the propagation speed of the longitudinal wave V_p and the shear wave V_s is:

$$v_p = \sqrt{\frac{\lambda + 2\mu}{\rho}} = \sqrt{\frac{E(1-\gamma)}{\rho(1+\gamma)(1-2\gamma)}} \quad v_s = \sqrt{\frac{\mu}{\rho}} = \sqrt{\frac{E}{2\rho(1+\gamma)}} \tag{2}$$

Where λ is the lame coefficient; μ is modulus of rigidity; ρ is the density of rock; E is the Elastic Modulus of the rock; γ is the Poisson ratio.
The relationship between the rock density and wave velocity is [LU JUN, WANG YUN, ZHAO WEI (2010), LI GUIHUA, ZHU GUANGMING, LI GUILIANG (2009), TENG JIWEN (2004) reported]:

$$\rho = 1.439(v_p \times v_s \times 10^{-6})^{0.2315} \tag{3}$$

It is obvious that if we know the speed of the longitudinal wave and the shear wave, the basic mechanical parameters of rock can be calculated according to the above formula.

3. The data acquisition of the multi-wave and multi-component seismic advanced detection and the interpretation principle of the adverse geological body

3.1 Field data acquisition methods

After many experiments and engineering validation, data acquisition method, follow these steps [WEN ZHANG, JIA LUO (2013) reported]:

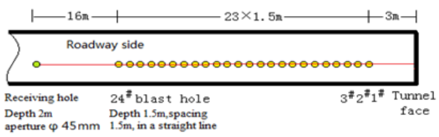

Figure 2: Field data acquisition method

①Decorate the holes, must be the 24 blast holes according to requirements (Depth 1.5 m, spacing 1.5 m, height 1 m, aperture Φ 42 mm) and a receiving hole (Depth 2 m, apart from the 24 blast hole 16 m, height 1 m, aperture Φ 45 mm).
②Charge, each hole in 80 g emulsion explosive, must use the instantaneous detonator.
③Hole sealing, with the anchoring agent plugging 24 holes more than 600 mm, in order to reduce acoustic interference.

④Detonation 24 shot points in turn, collect data at the same time.
⑤The acquisition work is over after 24 shot points detonated.

3.2 The interpretation principle of the adverse geological body

To transmit collected data to the computer, through the special data processing software for processing, the velocity profiles of the rock mass's vertical and horizontal wave and the change curve of the rock's various basic parameters will be got. In combination with geological condition analysis of these curves, could get forecast results of hard and soft, the degree of joint development, watery degree, etc. [WANSOO HA, et al (2012), WANG QIREN (2004), WANG DIAN, et al (2006), XU CHANG, et al (2000) reported].
There are several interpretation principles through a large number of engineering examples and the comparative study of the geological data:
① Fault, fracture zone and collapse column
Fault which is fracture and karst development zone that damaged rock mass integrity and continuity; the characteristic of the fracture zone depends on factors such as its material composition and degree of consolidation, etc.; the characteristic of the karst collapse column mainly depends on its composition, dry wet, silt content and other factors. The density difference is the obvious difference between them and the surrounding rock, with the different water level, has the different effect of elastic wave propagation.
In depth migration profile, those geological bodies have strong positive and negative wave reflection; reduce the vertical wave velocity, density curve ups and downs; if water is abundant, the shear wave reflection was stronger than p-wave reflection, the velocity's comparison of vertical and horizontal wave decreased, density increases; the static young's modulus is reduced, reflect the characteristics of the crack development, rock crushing.
② Soft rock
Soft rock such as mudstone and coal measures strata, carbonaceous slate or serious weathering fracture zone, small density, low strength, to the depth migration profile, which is characterized by strong negative reflection to the strong positive reflection.
③ Water cut, water storage structure
Fault fracture zone, unconformity surface and intrusive rock contact zone is often water-bearing structure. Loose structure, fracture development, rich in groundwater is their common characteristic, in the processing result, shear wave reflection stronger than p-wave reflection, p-wave velocity decreases, and shear wave velocity is not obvious changes, vertical and horizontal wave velocity ratio decreases, and the static young's modulus is reduced. There will be produced a positive reflection where the transition from soft rock into the water cut, water storage structure belt, the density increases.

4. The application of multi-wave and multi-component seismic advanced detection system in coal mines

4.1 The application of multi-wave and multi-component seismic advanced detection system in the Jin Mei Gu Shu Yuan coal mine

The data collected form multi-wave and multi-component seismic advanced detection are shown in figure 3. The processing results in figure 3, reflection interface drawn in the form of line, there are abnormal material reflection interface in those locations.

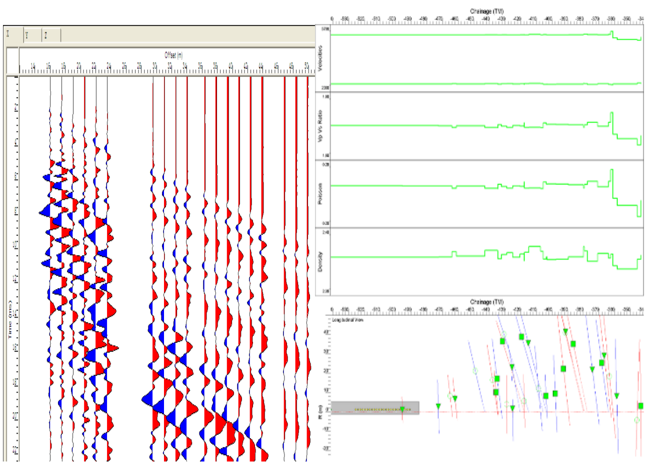

Figure 3: Raw data diagram and treatment results of Jin Mei Gu Shu Yuan coal mine

From the detection result, within the detection range is a clear geologic abnormal body interface. The stability of surrounding rock was poor in the scope of this geological forecast. It is mainly manifested in rock mass joint fracture development, the soft rock, the local water seepage. The large mined-out area didn't find in the detection range [YANG SITONG, CHENGJIULONG (2010), YUNBING HU, YAO WANG, YANQING WU (2014), YUNBING HU, YAO WANG, YANQING WU (2014), YANNING YU, et al (2015) reported]. Rock stability is poorer, prone to fall-block and collapse, detailed forecast results are shown in table 1.
After excavation, there are fault and fracture zone respectively in the front of the 46 m and 125 m, no omission.

Table 1: The forecast result of Jin Mei Gu Shu Yuan coal mine

Detection range (m)	Predicted results
0~18	Soft lithology, Some developmental fracture, Fractured rock mass, Easy to collapse, Fall-block, The stability of surrounding rock is poor
18~43	Soft lithology, Local development fracture, Some fractured rock mass, Easy to fall-block. The stability of surrounding rock is poor
43~80	The change of Lithology is bigger, Rock mass density is relatively larger, Some developmental fracture, Some fractured rock mass, Easy to fall-block, May be faulty, The stability of surrounding rock is poor
80~120	Soft lithology, Some developmental fracture, Fractured rock mass , Easy to collapse, Fall-block, The stability of surrounding rock is poor
120~135	Soft lithology, Development fracture, A lot of broken rock mass, May be broken belt, Easy to collapse, Fall-block, The stability of surrounding rock is very poor

4.2 The application of multi-wave and multi-component seismic advanced detection system in Gui Zhou Weng a coal mine

The data collected form multi-wave and multi-component seismic advanced detection system are shown in figure 4. The processing results in figure 4, reflection interface drawn in the form of line, there are abnormal material reflection interface in those locations. The tunnel face is the 0 m location in the detection results. According to the analysis processing, get the following conclusion: 21 m to 62 m in front of the working face within the scope of rock density is relatively large, but the joint fissure development relatively; 102 m in front of the working face exists a small fault; the rock density is high and complete from 102 m to 120 m; Other location which did not judge is not found abnormal. Detailed forecast results are shown in table 2.
After excavation, there are fault in the front of 95 m, no omission.

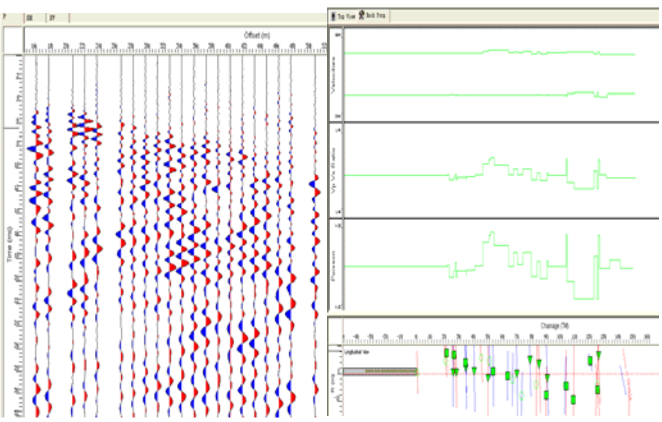

Figure 4: Raw data diagram and treatment results of Gui Zhou Wen An mine

Table 2: The forecast result of Gui Zhou Weng an coal mine

Detection range (m)	Predicted results
0~21	Lithology is better, Rock mass relatively strong and complete, The stability of surrounding rock is better
21~62	Rock mass density is relatively larger, Local development fracture, Local containing water, Some fractured rock mass, Easy to fall-block, The stability of surrounding rock is poor
62~102	Rock mass density is relatively larger, Some developmental fracture, Some fractured rock mass, Easy to fall-block, May be faulty, The stability of surrounding rock is poor
102~120	Rock mass density is relatively larger, Rock mass relatively strong and complete, The stability of surrounding rock is better

4.3 The application of multi-wave and multi-component seismic advanced detection system in recent years

In Songzao Coal, Jingyuan Coal, Zheng coal group, Yangquan coal group using multi-component detection technology and equipment were repeatedly advance detection of geological conditions in the experiment. As shown in Table 3. The average accuracy of advanced detection technology is 92%, and the detection range is 145 M.

Table 3: The detection and forecast result of recent years

Detecting location	Detecting time	Predicted location	Predicted results	Verification results
8411 Inner tail roadway	2013.5.22	Abnormal 112m	Fault	Yes
		Abnormal 87m	Fault	Yes
8129 intake airway	2013.5.31	Abnormal 75m	Nothing	No
		Abnormal 120m	Fault	Yes
8129 Inner tail roadway	2013.6.5	Abnormal 36m	fracture zone	Yes
		Abnormal 89m	fracture zone	Yes
		Abnormal 139m	fracture zone	Yes
8129 intake airway	2013.6.7	Abnormal 57m	fracture zone	Yes
		Abnormal 126m	fracture zone	Yes
83207 Inner tail roadway	2013.6.29	Abnormal 110m	Collapse column	Yes
8411 Inner tail roadway	2013.7.17	Abnormal 20m	fracture zone	Yes
		Abnormal 40m	fracture zone	Yes
8411 Inner tail roadway	2013.8.8	Abnormal 50m	Nothing	No
		Abnormal 75m	Fault	Yes
		Abnormal 110m	Fault	Yes
83207 Inner tail roadway	2013.8.9	Abnormal 30m	Collapse column	Yes
		Abnormal 80m	Collapse column	Yes
No. five belt Lane	2013.9.18	Abnormal 30m	Collapse column	Yes
		Abnormal 67m	Collapse column	Yes
		Abnormal 98m	Collapse column	Yes
8413 intake airway	2013.11.27	Abnormal 30m	fracture zone	Yes
		Abnormal 56m	fracture zone	Yes
		Abnormal 79m	fracture zone	Yes
The south area two track roadway	2014.5.18	Abnormal 63m	Fault	Yes
		Abnormal 145m	Fault	Yes
83207 return air course	2014.6.24	Abnormal 60m	Collapse column	Yes
		Abnormal 89m	Collapse column	Yes

5. Conclusions

Through analysis the seismic exploration theory of the multi-wave and multi-component in front of the paper and combined with the adverse geological interpretation principle for inversion interpretation of coal mines, from the forecast results are obtained:
① Detection range is above 100 m, the maximum detection range of 145 m. The average accuracy of advanced detection technology is 92%.
② It can accurately detect the fault, fracture of surrounding rock, rock fracture zone, and the water-rich circumstance, miss probability is low.
Multi-component detection technology and equipment provide a more reliable means for coal mine long adverse geological advanced prediction. It must get extensive application in the coal mine for safety production.

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