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Characteristic of geological anomaly detected by combined geophysical methods in a deep laneway of coal mine

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Abstract

The driving safety in deep laneway is often affected by many geological anomaly factors in ahead of a laneway end. The variability of rock properties, faults and so geological anomaly have relations with groundwater in rock mass. Therefore, it is necessary to employ various geophysical methods for geological anomaly detection in the front of laneway end in order to avoid mine inundation, which guides the process of driving in a laneway of coal mine. According to the comparative analysis between geological exploration and various geophysical methods used in the 2000m-passageway of -780-south section in Guqiao coal mine of Huainan, the result shows as follows. 1) The abnormity of lithology and faults can be detected and forecasted by the reflected seismic wave in the laneway, long distance prediction and high resolution detecting ability are the main characters of the reflected wave method, and the spectrum characteristics of seismic wave can distinguish the change of lithology; 2) The transient electromagnetic method (TEM) is very sensitive to solve the change of aquosity in terrane ahead of the laneway heading face, and the relatively characteristics between lithology change and its containing water can be identified finely through the direct current resistivity method in laneway; 3) The relatively characteristics between lithology change and its contained water can be identified finely through the direct current resistivity method in laneway. In a limited space of laneway, the combined analysis method using variety of geophysics methods are an effective method to detect geological anomaly and hydrogeology ahead of the laneway end, which can provide a powerful technology for safety and efficient driving in a deep laneway.

keyword: multi-information of geophysics; geological anomaly; advanced detection; deep laneway

1. Introduction

The driving safety in deep laneway is often affected by many geological anomaly factors ahead of the laneway end. The abnormity of engineering geology such as the mechanical property of rock stratum, fault and aquosity, is the controlling factors during the driving period of the deep laneway of coal mine. The outburst disasters are often

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be met in the face of laneway, for example fault, collapsing bound, water inrush, gas outburst, and digging empty area, etc. Therefore, advanced prediction for geological conditions ahead of the laneway is important for the modern subterranean projects. Confined by the observation space in the laneway, the exploring method is limited, and the exact forecast for geological structure has great difficulty. The fore detecting belongs to the orientation problem for the concealed objects. Though many geophysics methods can be used, different methods have respective constructing difficulty and affective factors. The exploring results and precision couldn't meet the need of the engineering technology development because of the limitation of underground 3D space; fortunately, the localization veracity for the geological anomaly during the construction of the laneway can be improved obviously through measuring and combined geophysics methods in the laneway.

2. Combined geophysical detecting methods

Currently, many geophysical detection methods can be used in the laneway, and the main methods include the elastic wave testing method, the DC resistivity method, the transient electromagnetic method, and infrared detection, etc. Because each kind of geophysical exploration method has its own characteristic and applying condition, it has the different emphases to solve the geological problems. The single method is hard to analyze effectively the comprehensive information of geological anomaly, and the combined geophysical detection technology can get the optimum result.

2.1. Deep mine laneway exploration geophysical conditions

For the comprehensive advanced detection in the mine laneway, it solves mainly the interface problems of coal and rock, rock fracture zone, and so on. The coal seam is a kind of special medium, and it has significant differences compare to the roof and floor of it. Generally, the coal seam belongs to the weak layers which have the low density and the low speed in the coal measure strata. According to the theory of wave impedance, the average density parameter is 1.3g/cm^3 for the coal seam and 2.6g/cm^3 for the surrounding rock. The average seismic wave speed is 1200m/s for the coal seam and 3500m/s for the terrane. The reflection coefficient is around 0.5. It indicates that the interface between coal seam and rock is a strong reflection interface. It is beneficial to do the seismic wave exploration for solving the structure and construct in the coal measure strata. In the deep laneway of coal mine, the surrounding rock loose circle can be formed generally due to the local stress concentration in the laneway. It causes that the excitation and receiving conditions of seismic wave is uneven, and this is a difficult problem about seismic exploration in practical engineering laneway. A tentative summary, the varying of P-wave velocity is shown in table 1[1].

Table 1. The feature list of the surrounding rocks P-wave speed in deep coal mine laneway accessory

Vp (m/s)	The original rocks	Tunnel loosening circle	Tectonic belt
Limestone	4000~4500	1000~4000	3000~4000
Clastic rocks	3000~4500	600~3000	2000~4000
Coal seam	1000~3000	200~1000	1000~2000

Usually, different lithology of electrical parameters such as resistivity value are different in coal measure strata, the same terrane has a varying resistivity value due to its structure changes. The resistivity value about the coal seam is higher and it is around 300 Ω m, but the resistivity value about the laneway of roof and floor is lower and it is around 100 Ωm. The resistivity value of water body in the coal seam is around 10 Ωm. In the primary non-structural state, the change discipline of stratigraphic conductivity is stable relatively in longitudinal and transverse directions. When the strata changes, for example, when it meets fault belt or water-contained, its conductivity changes greatly, local resistivity value is abnormal, so we can judge the geological abnomity according to the basic characteristics of the terrane's electrical property in longitudinal and transverse directions. This is the geological basis of laneway electromagnetic advanced detection.

2.2. The common method of geophysical prospecting used in the laneway

The main geophysics methods include MSP method, laneway DC electrical method and the transient electromagnetic method. It can improve the judgment reliability for the geological conditions in the laneway excavation ahead, and provide some geophysical information for the deep mine laneway excavation construction.

2.2.1. Mine seismic prediction method (MSP)

Mine seismic wave advanced detection system is an advanced detection system which is exploited on the basic of other advanced detection methods such as the tunnel seismic prediction technology (TSP), negative visual velocity seismic reflection method, etc. This observation system applies the reflected wave exploration principle that the seismic wave can produce reflection when it encounters the uneven geological-mass (that exist wave impedance differences) during the propagation process. Combined with the character of laneway, data collecting system of the source and sensor is designed along the laneway behind the face to detect geological conditions ahead of laneway. The prestack migration method is used in data processing. It gets the geological interface information ahead, and it is the jointed seismic exploration technique of the multi-wave and multi-component. The depth migration profiles of the P wave and S wave ahead of the laneway can be gained and the reflection layers are extracted [2-5]. And it can determine the space position of geological interface corresponding to the reflection layer. And the properties of geological object can be explained according to the combined characteristics, dynamics characteristics and rock physics and mechanics parameters and other data of the reflected wave. Site layout is shown in Fig.1.

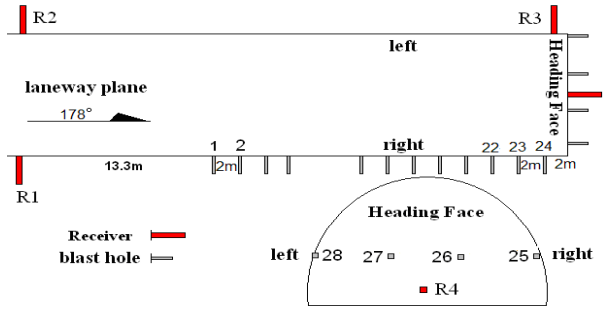

Fig. 1. MSP leading detection disposal

The MSP method is different from TSP, and it includes that the stimulate and receiving method, for example, the MSP method has arbitrariness and diversity, adaptive τ-p transformation separation wave field, and many geophones in different space position, which can receive the reflected wave of the different attitude geological interface. It increases the redundant allowance of stack migration data and the migration profile effectiveness is enhanced [6-7].

2.2.2 .DC sounding method of three electrodes in the laneway

Leading detection of triple-pole DC electrical method in the laneway is based on the DC electrical sounding principle to finish advanced detection in the laneway [8-9]. For point source fields in 3D space, with source electrode as the centre of the sphere, electrode distance measurement of MN as data recording point, it reflects media resistivity of spherical shell volume that thickness is MN and AO is radius. According to the principle of symmetrical, along with increasing distance, OA detection range is increasing. It is identical with detecting the electrical property change of the anterior ped of symmetrical powering point, forming a laneway triple-pole anticipate probing technique.

On the basis of the triple-pole DC electrical sounding principle, and combining with parallel electrical technique[10], and condering the face of laneway as the center, sixty-four electrodes are arranged regularly during advanced detection, thereby it forms tridimensional DC electrical method system. Fig. 2 shows the multi-polar electrical method leading detection arrangement plan. An electrode takes turns back slipping from head-on laneway, whereas B electrode park infinite distance. This testing system at head-on laneway proceeds disposable electrode disposal, both source electrode and measuring electrode approve discretion disposal in laneway space, but in order to convenience disposal the electrodes are often arranged on the same testing plane. Owing to large data gained from

multi-polar superposition observing system, superposition operation can be proceeded, which enhances greatly the accuracy rating for geological construct prediction [11-13].

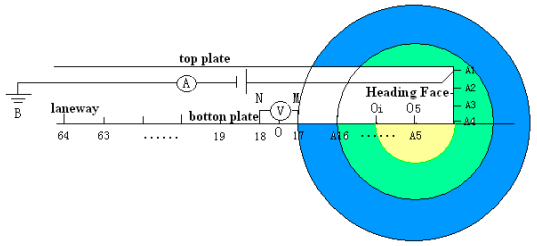

Fig. 2. Triple-pole electrical method leading detection

2.2.3. Transient electromagnetism advanced detection

At the laneway face the multi-turn superimposition transmitting and receiving antenna is put to proceed mine transient electromagnetic method detection. By induced electromotive force time-variation characteristic it is known that electromagnetic properties of face laneway nearby media how change it is, thereby it can ascertain the scale of the electromagnetic properties anomalous body, attitude and the distance to head-on laneway, etc[14,15]. (Fig. 3) is laneway leading detection direction and disposal sketch map. By computing electromagnetic induction apparent resistivity of time domain, it can verdict anomalous body ahead of laneway and its characteristic of containing water.

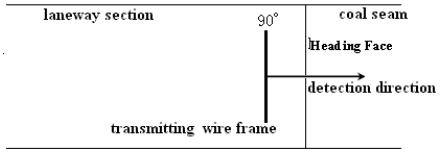

Fig. 3. Laneway transient electromagnetism leading detection direction and disposal

2.3. Combined utilization of the multiunit message

According to the difference of rock geophysics property, it can abstract several property parameters such as seismic wave reflected energy, wave velocity and resistivity interfaces, natural potential, and so on. Owing to sensitivity degree difference from laboratory experiments, wherefore it can utilize attribute abnormity amplitude to verdict different geological objects. For the moment it primarily utilize energy abnormity of elastic wave to infer fault interfaces, and resistivity difference to verdict containing water character of rock stratum. Through combination explanation of the multiunit message of the seismic wave and electrical method, geological anomaly ahead of laneway can be assessed. But fusion calculation among multi-unit message data should be lucubrated in the future.

3. Guqiao coal mine detection practice

3.1. Detection engineering practice

Guqiao coal mine is an oversized mine of Anhui Huainan Mine Group, and rated annual capacity is ten million tons per year. #11 and #13 coal seams are cutting firstly, and exploiting -780 south-section laneway is critical productive task, which is important to realize mine layout. According to drill and 3D seismic map, many complex geologic structure zones are existed in south-section laneway ahead of laneway face. A larger number of faults whose fall are comparatively large, attitude of rocks which change strongly, coal seam gasses, sandstone water which exist in coal measures, this geological disasters should bring great threat to laneway security construction and shoring.

In October, 2006, F92 fault is exposed in the -780 south-section laneway, and lithology disintegrate in the distributed fault and major water gushing phenomena is found when laneway disclose fault. This laneway driving belongs to complicated geohydrologic condition. For ensuring driving safety of laneway, mutil-information of geophysics survey technique is used at the scene, and continuous follow-up detection is adopted, the character of rock containing water and fault construction ahead of laneway face are found in time, and the geological anomaly is drilled for demonstration. And pre-grouting measure of deep-and-shallow hole to wall rock is used to ensure the safety of laneway driving through complex geological structures.

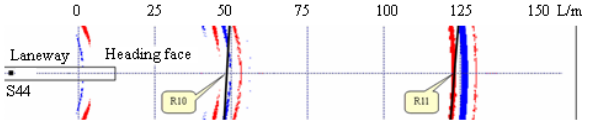

Fig.4 MSP seismic wave energy migrated section

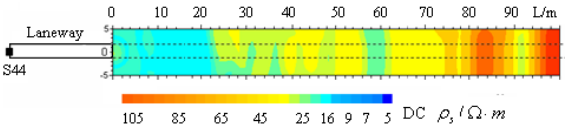

Fig.5 DC advanced detection apparent resistivity section

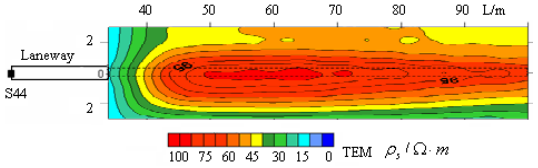

Fig. 6. TEM advanced detection apparent resistivity section

3.2. Practical detection operations

On the practical detection, construction interfaces about 150m ahead of laneway are controlled by MSP, and containing water abnormity about 100m is controlled individually by DC electrical method and TEM. Here, one example is given. On January 30, 2008, with a measuring point S44 in the laneway for zero we analyzed detection disposal.

Three receiving points are fixed in MSP method, each point adopts perpendicular X, Y, Z three-component velocity type seismometer(dominant frequency for 100 Hz), and X-direction is arranged parallel with laneway and is pointed to laneway face direction. It adopts instantaneous cap and 80g emulsion explosive to blaze. According to 3500 m/s uniform speed migration, anterior reflected energy homing chart after adaptation τ-p transform desquamation of wave field is gained (Fig.4).

Leading detection of multi-pole direct current electrical method, each time at laneway floor dispose sixty-four electrodes, from laneway face to rear, electrode number take turns one to sixty-four. As source electrode, a take turns from one till sixty-four as power supply, every time power supply 2s, other sixty-three non-source electrode together measure potential difference in comparison with electrode N, and electrode B is put at 500m site of laneway backside. According to total space case theory adopt former thirty source electrodes to compute anterior apparent resistivity. The anterior apparent resistivity section (Fig.5) can be given.

TEM adopt left side, right side and face of laneway to arrange transient electromagnetism measuring line, one left, and right side assign five points respectively, measuring distance 3m; face side arrange seven measuring points, measuring points span 0.5m. Separation angle of transmitting loop plane normal direction and laneway is 0°, and separation angle of receiving coil plane normal direction and laneway is 0°. Aim is predicting anterior terrane characteristic of containing water. Detection result is as in (Fig. 6).

From Fig.4, it is observed that from laneway S44 point to anterior 200m, two group main reflection abnormity interfaces, parting for R10 and R11, 70.0m and 142.5m calculated with s44 point. It is observed that from multi-pole electrical method result (Fig.5), Within the scope of 150m calculated with S44 point ahead of laneway, whole resistivity is all above15Ωm, and no apparent is low resistivity anomalous zone.

TEM achievement (Fig. 6) also is symptomatic of that: this zone resistivity is higher. Integrating with three

geophysical information outcomes, it infers this volume of investigation lithosome which is not abundant with water. Practically neighborhood of R10 is the branching fault of F108-1(fall H=5.5m,□50~85º.5); R11 appear 0.2m coal streak, lithosome phase grow into grittiness mudstone which is not contained with construct, part spraying of water phenomena is found within head-on laneway during the excavation.

3.3. Lithology and seismic wave spectrum

15 times detection by MSP is finished to keep surveying -780 south-section laneway of Guqiao coal mine. Fig. 7 indicates the relationship of the rock attribute and the seismic spectrum characteristic which on the conditions of small bomb source and using 100 Hz velocity seismometer. It can be seen that the spectrum of the deep department is mainly distributed over the frequency from 30Hz to 700Hz and its frequency is mainly scattered during 10Hz and 1200Hz. Different rock attribute part has obvious distribution in the wave spectrum, the main frequency of the mudstone is thinner than others and the frequency is not abundant, such as 450, 280, and 150Hz. And the main frequency of the complete sandstones is 500Hz, which is sufficient, but the main frequency of the broken ones is only 320, 220, and 120Hz, respectively. As a result, the frequency is very useful in distinguishing the lithology and rock hardness.

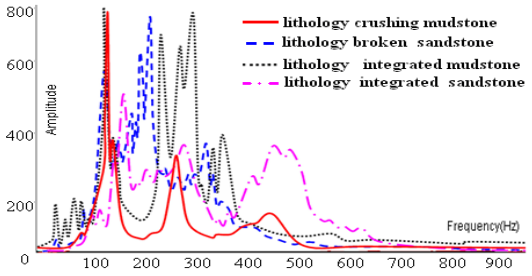

Fig. 7 Lithology and seismic spectrum

3.4. Contain water detection evaluation

The results from multi-pole method and TEM advanced detection are shown in Fig.8 andFig.9 respectively. It can be seen form that, the resistivity is less than 10Ωm between 0-25m and 40-60m Fig.8, and the resistivity turns small in the section of 46-60m from Fig.9, so there may contain a lot of water at the front of face. After confirmation of tunnel excavation, it is found that it was the mudstone (the resistivity is low) at the 0-25m from the front of head-on laneway. And the rock turned to sandstone when it crosses FD76 at the front of head-on laneway. It appears water and the drum, the volume of outleting water is 10 m^3/h. So, when the mudstone resistance of multi-pole resistivity sounding is less than 10Ωm and with the match of abnormality of TEM, it can judge that the possibility of success is almost 90 percent.

At present, it completes almost 2000m, and it gains great actual effect by collecting and tackling the multi-information of geophysical information. It has a series of guiding meaning to the security of the tunnel excavation. DC electrical method and TEM are sensitive in the survey of water ahead of the laneway.

4. Conclusion and existing problems

The continuity of MSP is very good in prospecting the front geological structure from the result of the active tunneling. The energy interface of the seismic wave is induced by fault structure, and broken belt are obvious. The reliability of fault judgement is more than 68 percent and 80 percent in the distance. The comprehensive application of the multi-information by MSP and electromagnetic

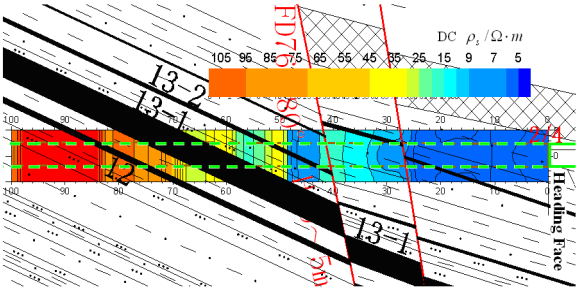

Fig. 8. FD76 fault direct current electrical method result

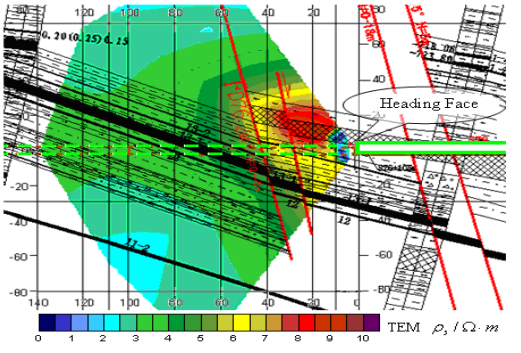

Fig. 9. FD76 fault TEM result

method can enhance the accurate degree of the objective prospect in a large extent, and it can offer much more proper and reasonable judgement. The multiple use of the three methods can improve the explain accuracy degree to more than 80 percent.

Just it say the technology, MSP must intensify the research of 3D data acquisition method and migration velocity analysis. Multi-pole sounding lead detection method is affected easily by the space. It must strengthen the research of the method of data inversion. TEM advanced detection should build relative steady resistivity inversion algorithm and depth coefficient. The development of all those technology should make the quantitative advance geological forecast of deep laneway.

Multi-information of geophysics exploration in the deep laneway, which uses sufficiently the advantages of all kinds of physical survey methods and analyzes comprehensively the different survey results, which lead to more dependable results. Using geophysical survey results to help fix up the drilling hole and construction on-site, and both effective cooperation, and it provides certain geological security for complex geological conditions of laneway excavation safety, which is the development direction of advanced detection technique.

Acknowledgements

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