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Application of Transient Electromagnetic Method and Seismic Profile Method in Advanced Forecast

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Abstract

At present, with the mining of deep coal seam, the geological structure conditions are more and more complicated, which makes the processing and interpretation of single geophysical prospecting method more difficult. To solve this problem, a comprehensive advanced detection technology combining TEM and seismic profile method is proposed, that is, seismic profile method is used to detect the structural development in the working face, and TEM method is used to detect the distribution of water-rich abnormal areas in the working face, roof and floor. The possible water-conducting structure and the location of water-rich abnormal area can be accurately detected, and the advanced detection of water inrush disaster can be realized from two aspects.

Keywords

Advance Detection; Transient Electromagnetic Method; Seismic Profiling.

1. Introduction

The hydrogeological conditions of coal mine in China are complicated, and water accidents happen frequently. According to the statistics released by The National Coal Mine Safety Administration, from 2006 to 2018, a total of 438 coal mine water accidents occurred in China, resulting in 1,911 deaths, causing major economic losses and social impact [1].

At present, the water damage problem in the mining of deep and lower coal resources is becoming more and more serious as the reserves of easy coal resources in shallow and upper coal groups are gradually exhausted. The hydrogeological conditions of mine water filling are becoming more and more complex, and the influencing control factors of water inrush are increasing, and the mechanism and types of water inrush are complex and changeable [1-3].

Geological structure provides the occurrence space and water channel for underground water, controls the distribution and migration of water, and is the key factor to form mine water inrush. The advance prediction of concealed geological structure can effectively prevent the occurrence of mine water hazard and provide design basis for water hazard control and mining work. At present, drilling and geophysical exploration are the main advanced detection methods for geological structures [1]. Drilling is the most direct and effective method of mine water exploration and drainage, but compared with geophysical exploration means, drilling engineering takes long time, low efficiency and limited detection range, so it is difficult to fully reflect the geological structure within the regional scope. As

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a long distance and rapid nondestructive detection method, mine geophysical prospecting is playing an increasingly important role in the advance prediction of concealed geological structures.

As a non-contact geophysical prospecting method, TEM also shows obvious advantages in detecting water-conducting structures [4,5]. Seismic profile detection method is more effective in detecting abnormal interface and determining the spatial position of abnormal body [4]. Because the geological structure destroys the continuity and integrity of rock mass, the structure or structural fracture zone has obvious impedance difference compared with surrounding rock, which can be well identified in seismic profile detection method. At the same time, the geological structure breaks the original stratigraphic electrical anomaly interface differentiation law, if the structure does not contain water, local resistivity value increases; If the structure contains water, the resistivity will be reduced, which provides a good geophysical premise for the advance detection of seismic profile detection method and the implementation of mine transient electromagnetic technology [1].

At present, with the mining of deep coal seam, the geological structure conditions are more and more complicated, which makes the processing and interpretation of single geophysical prospecting method more difficult. Aiming at the structural and water detection difficulties of roadway heading face, in order to accurately locate the geological structure position in front of roadway and judge its water wealth, seismic profile detection method and transient electromagnetic method can be combined to carry out targeted advance exploration.

The seismic profile detection method has a small distance error and is more accurate in describing the spatial location of abnormal structures, but it is not sensitive enough to detect water-bearing abnormal bodies. Transient electromagnetic method can be used for multi-angle and multi-sector detection, but the volume effect is significant, the anti-interference ability is poor, and the environment is seriously affected. Transient electromagnetic method and seismic profile detection method can be used to jointly explore the location of the water-carrying/conducting structures developed to coal seam. To develop to the coal seam of concealed contain/conducting water of collapse, not directly formed near the water channel, but under the coal seam working face mining disturbance will lead the water channel, radio wave perspective method not easily proved its position, can use impedance difference of collapse column and surrounding rock, seismic profile detection method is used to probe the scope of its development.

2. Geophysical Prospecting Technology of Mine

Taking a mining area of Shanxining coal mine as an example, the working face of this area corresponds to the development of surface scarps, and the surface fluctuation is large. The floor elevation of coal seam in working face is 209-227m, the ground elevation is 580-780m, the thickness of cover mountain is 371-553m, with an average of 462m, and there are no other buildings and protected cultural relics on the surface. According to calculation, the thickness of the safe waterproof layer between the 2# coal seam and the Ordovician limestone aquifer is T =2.74m, less than 73m. Therefore, during the tunneling period, it is basically not affected by ordovician limestone water, but in the case of water-conducting faults and water-conducting collapse columns, the floor water-repellent layer basically loses its water-repellent ability, and there is a great risk of water inrush. Therefore, the working face needs to pay close attention to the development of faults and other structural bodies in the area to prevent the occurrence of structural water diversion phenomenon.

2.1 Transient Electromagnetic Method

TEM is a time-domain electromagnetic induction method. Its detection principle is to use no earth, no polarization loop geologic abnormal body object to be detected emission electric pulse type electromagnetic fields at a time, in the square wave pulse after the fall, to generate a return to the normal direction of the spread of a magnetic field, under the stimulus of a magnetic field, abnormal geologic body will appear abnormal eddy current field, its size mainly depends on the abnormal degree of conductive geological body, After the disappearance of the primary field, the secondary vortex will not disappear immediately, and there is a transition and progressive decay process [5-6].

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In this transition process, a attenuating secondary magnetic field propagates to the palm surface, and the secondary magnetic field is received by the receiving loop. The evolution of the secondary magnetic field with time T indicates the electrical properties and geoelectric field distribution of abnormal geological bodies at different depths H. At any moment, it is bound to a depth of eddy current generated by the surface corresponding to the electromagnetic field can be equivalent to a horizontal transverse circular current of the electromagnetic field and change over time and quickly spread outward, the equivalent electric current ring is like come from launch without polarization coil "loop", will be induced current to flow in a process of diffusion around the image is called the "smoke ring effect", As shown in Fig. 1, the change of the secondary magnetic field will reflect the electrical distribution of the geological body. The apparent resistivity of the target medium at the corresponding depth can be obtained through the effective calculation of the apparent resistivity and the calculation of the electromagnetic wave diffusion depth, so that the geological information and water level geological information within the detection range can be predicted [7].

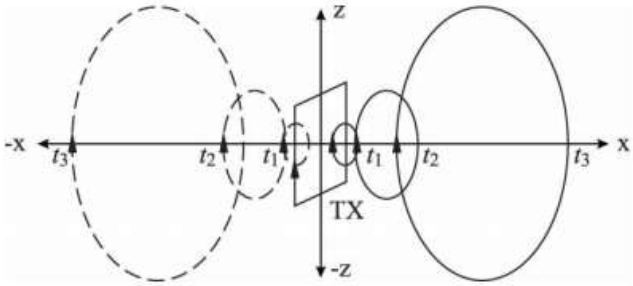

Fig. 1 Schematic diagram of smoke ring effect

2.2 Seismic Profile Detection Method

Seismic exploration is an exploration method that uses different media with different elastic properties to explore by studying seismic wave fields. The seismic wave profile exploration method is a method of exploration by studying the refraction and reflection of seismic waves when they meet the interface with different wave impedance when propagating in the stratum.

Using artificial source manufacturing seismic wave in the formation of transmission, the local seismic waves meet fault and collapse column, lithological change area, due to the medium wave impedance changed seismic reflection happens, reuse plug in advance good detector in chronological order, receive reflected in the area of seismic signal, the signal processing and analysis of seismic waves received, on the basis of The spatial position, structure, physical property and geometric form of the underground target are inferred according to the parameters of signal waveform, intensity and two-way travel time, and then the geological information and water level geological information within the detection range are inferred [4].

Seismic profile detection is shown in Fig. 2.

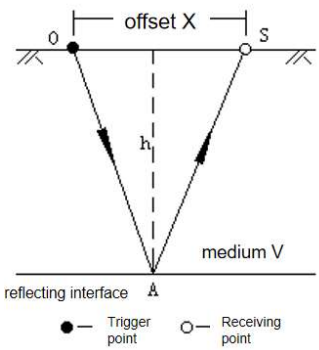

Fig. 2 Schematic diagram of seismic profile detection method

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3. Practical Application

3.1 Geological Profile of Water Level in the Mining Area

The surface corresponding to the working face of the area is arable land and barren hills, the surface is mainly eroded loess ridge, gully development, part of the area has exposed rock. The working face corresponds to the development of surface scarps and the surface undulation is large. The coal seam floor elevation of working face is 209-227m, the ground elevation is 580-780m, the thickness of cover mountain is 371-553m, with an average of 462m, and there are no other buildings and protected cultural relics on the surface.

The whole area of the 2# coal seam of the working face is stable and recoverable. The thickness of the coal seam is 5.9 ~ 6.4m, with an average of 6.15m. The structure of the coal seam is 4.0(0.25)2.15. The overall coal seam of the working face inclines to the northwest, with a dip Angle of 0°~ 12°, generally 2°.

The main water filling factors in the tunneling process of working face include surface water, sandstone fissure water of roof, limestone water of Taiyuan Formation of floor and Ordovician limestone karst water of floor.

3.2 Detection Results and Analysis of Seismic Profile Detection Method

The main purpose of the headface construction at 5m of 2203 main lane is to detect the structural development of roadway heading direction. Based on the mission and purpose of this detection, combined with the downhole construction environment, this detection adopts the reflection common migration method (Fig. 3) for observation, and the hammer direction is consistent with the direction of the detector. According to the actual geological situation and the purpose of the task, the detection position is arranged as the starting point of the detection point, and the detection is performed every 80m. Each detection cycle produces 3 tracks of data by hammering a measuring point, 12 times in total, and 36 tracks of data in total.

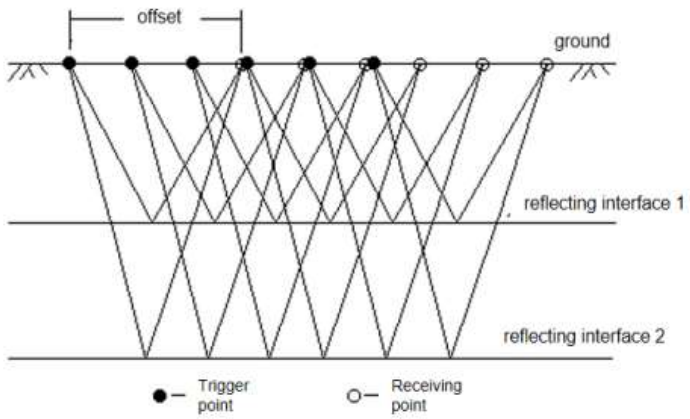

Fig. 3 Schematic diagram of survey line layout by seismic profile detection method

The data obtained from the detection is processed. The data processing process is briefly as follows: the original seismic wave data from underground detection is fed into the computer, and then the two-position imaging profile of seismic wave is obtained through spectrum analysis, one-dimensional filtering, two-dimensional filtering, velocity fitting and migration imaging in the processing software in sequence.

Detection section of seismic wave profile imaging technology at 5m in front of 2203 main Lane (Fig. 4) analysis:

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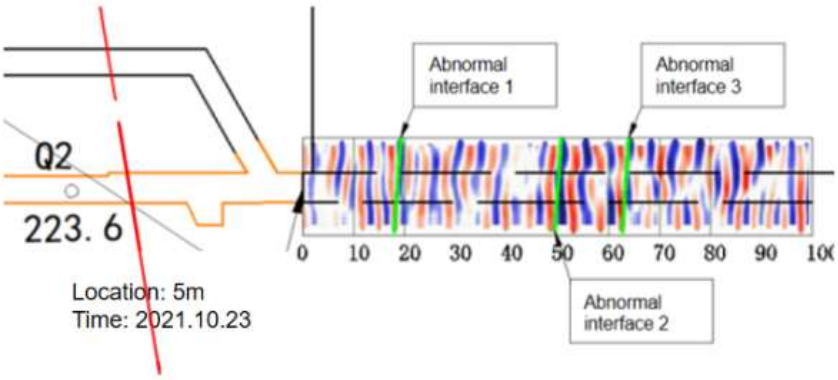

Fig. 4 Imaging section of seismic wave profile

There are abnormal waveform interface 1, abnormal interface 2 and abnormal interface 3 within the detection range, and the detection location is 5m. The exception is explained as follows:

Abnormal interface 1:18m directly in front of the roadway head, abnormal interface 1 was analyzed to be fault or joint fissure development.

Abnormal interface 2:50m in front of the roadway head, abnormal interface 2 is characterized by faults or joint fractures.

Abnormal interface 3: in the range of 63m in front of the roadway head, abnormal interface 3 is a joint and fissure development zone.

According to the results obtained by seismic profile method, it is speculated that there may be fault development and water inrush risk in the working face.

3.3 TEM Detection Results and Analysis

The main purpose of the headface construction at 5m of 2203 main lane is to detect the structure of roadway heading direction and judge the water bearing capacity and distribution of rock strata within the detection range.

Based on the detection task and purpose, combined with the downhole construction environment, the detection adopts the overlapped loop device (Fig. 5) for observation. The transmitting coil and receiving coil overlap plane, and the axes of the two coils point to the detection direction.

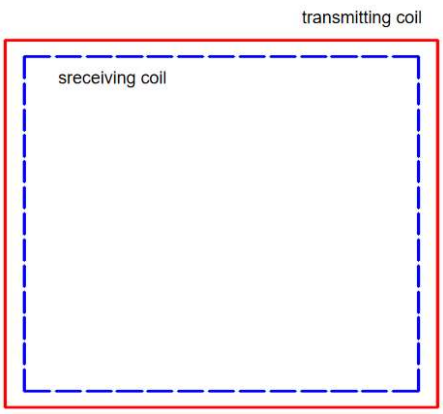

Fig. 5 Schematic diagram of overlapping loop device

In advance detection of heading face, detection is carried out in multiple directions according to different angles and accurate control of detection orientation, so as to obtain as complete hydrogeological information in front of heading face as possible.

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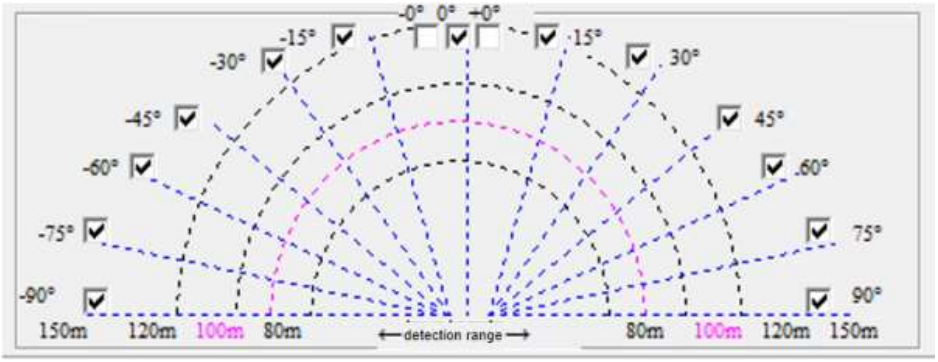
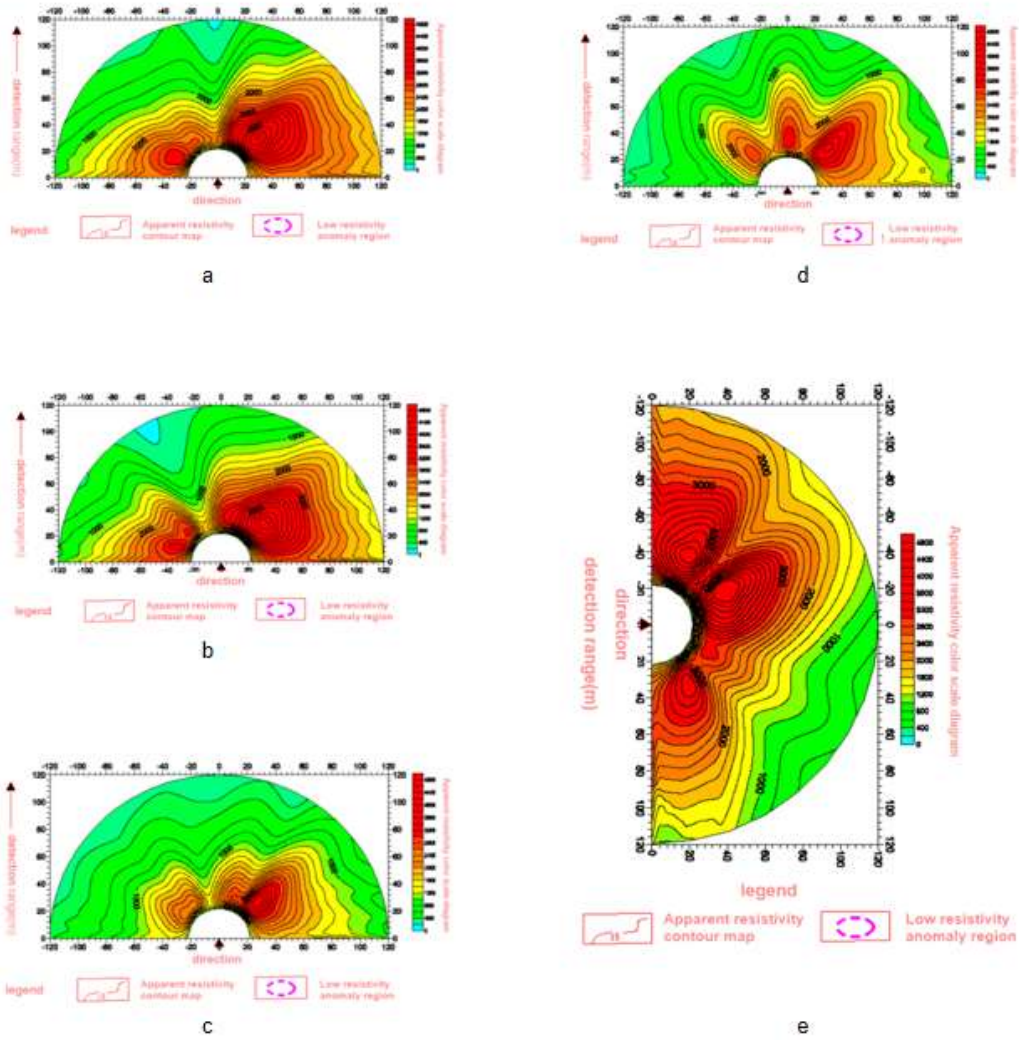


Fig. 6 Schematic diagram of semi-circular measurement point layout on headface



a).45-degree fan section of the roof for TEM advanced detection
b).30-degree sector section of the roof for TEM advanced detection
c).0-degree fan-shaped section of the TEM advanced detection along the bedding
d).30-degree sector section of the TEM advanced detection base plate
e).Front 0-degree longitudinal section of TEM advanced detection

Fig. 7 section of the TEM advanced detection

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The data obtained by detection is processed, and the data processing process is briefly as follows: After the original secondary eddy current magnetic field data from underground detection is fed into the computer, the apparent resistivity value of the stratum is calculated and converted into distance through positive and inverse calculation through various corrections and special transformations in the special processing software for mine transient electromagnetic in sequence. Then, according to the obtained full-space apparent resistivity value, Combined with various geophysical and geological factors such as detection distance, detection direction and formation dip Angle, a special high resolution resistivity imaging method is used to obtain the apparent resistivity section map of transient electromagnetic detection.

The transient electromagnetic detection blind area is about 20m. Contour in the apparent resistivity profile measured values for the transient electromagnetic exploration of rock relatively apparent resistivity value of colors from red to blue said apparent resistivity value from high to low relative changes, the smaller the value (corresponding to the color blue) show that formation apparent resistivity value is lower, there may be more broken rock, fracture or relative water content, the better. It is also the key point to pay attention to in the process of water exploration and excavation. The probe was conducted in the horizontal direction of 0 degrees.

According to the analysis of transient electromagnetic advance detection chart, there is no obvious low resistance abnormal area within the detection range.

4. Conclusion

Due to the existence of water-conducting fault and water-conducting collapse column, the bottom water-isolating layer basically loses its water-isolating ability, and there is a great risk of water inrush.

Therefore, in the frontal detection of this area, it is necessary not only to accurately depict the position of water-bearing abnormal body, but also to obtain detailed geological structure information of the frontal body and accurately locate the possible water-conducting faults and water-conducting collapse columns, so as to achieve prevention and control.

Through comprehensive analysis of composite exploration data, it is concluded that although the low resistivity anomaly areas explained in the TEM results are relative. The interpretation of anomaly area and detection range will have some deviation, but the relative high and low trend of apparent resistivity value in the result diagram is reliable. According to the transient electromagnetic detection results, there is no obvious low-resistivity abnormal body in the area between 20m and 80m in front, and the seismic profile detection results suggest that the possible faults and fractures are not water-bearing.

At the same time, through the transient electromagnetic bends down, back and longitudinal profile, you can get ahead of tunneling faces, roof and floor water information by detecting results can be speculated that face ahead of 20 m - 80 - m within the scope of roof and floor are abnormal, there is no water cut right in front of roadway in near 50 m and 63 m near the fault or joint development with the possibility of water inrush is low. It is proved that the combined exploration of TEM and seismic profile method can effectively complete the advance detection task by the actual excavation prediction.

Acknowledgments

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