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Research and Application of Advanced Detection of Water Hazards in Coal Mine Bore-Hole

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Abstract

For many years, the "short excavation and short exploration" excavation mode has been mainly used in the underground tunnel excavation of coal mines, which is difficult to meet the needs of rapid tunnel excavation. For this reason, CCTEG Xi'an Research Institute has innovatively proposed a new working mode of "long excavation and long exploration" using directional long drilling and borehole geophysical exploration. This method utilizes directional long boreholes that have already been constructed, and uses transient electromagnetic technology in the borehole to detect the radial range of 30 meters and the depth exceeding 1000 meters of the borehole, ultimately forming a three-dimensional imaging of the entire spatial geological anomaly body, providing reliable technical support for the safety and long-term excavation of the tunnel. This paper introduces the application which is a long-distance advanced detection of 1026 m.

Keywords

Transient Electromagnetic Method, Bore-Hole Transient Electromagnetic, TEM, Geophysical Exploration

1. Introduction

In recent years, an important task in coal mine construction and production has been to prevent water accidents from occurring. This has given rise to various water prevention and control technologies, mainly advanced geophysical exploration and advanced drilling techniques. Geophysical exploration takes the lead in drilling due to its advantages such as low labor intensity, high efficiency, and wide coverage. Drilling mainly detects and verifies geophysical anomaly areas

[1] [2]. Transient electromagnetic method is one of the rapidly developing and widely used geophysical methods in recent years. Due to its advantages of good detection effect and simple construction technology, it has been increasingly used in coal mines.

With the breakthroughs in key technologies such as theory, methods, and instruments for transient electromagnetic detection in coal mines, the technology and equipment for transient electromagnetic detection in coal mines have been widely promoted and applied in major coal mines across the country, and have become the main geophysical means for advanced water exploration in coal mine excavation faces [3]-[5]. Combined with advanced water exploration and drainage drilling engineering, it meets the technical requirements for advanced water exploration and drainage work in coal mines underground [6]. Li Xiu of Chang'an University, Fan Tao of Xi'an Research Institute of Middling Coal Technology and Industry Group, etc., have all carried out research on pseudo seismic interpretation of transient electromagnetic data, enhanced the ability of transient electromagnetic to solve geological problems, and demonstrated broad application prospects of this technology [7] [8]. However, transient electromagnetic method has quite strict requirements for the surrounding environment of tunnels and is easily affected by low-resistance objects from the outside, such as drilling machines, belt conveyors, anchor rods, etc. Not only does it cause errors in data collection, but it also inevitably leads to multiple solutions for later data processing and interpretation. In addition, the application effect and accuracy of this method in practice are far from meeting the requirements of geological work [9] [10].

Introducing transient electromagnetic waves into underground drilling has to some extent expanded the application field of transient electromagnetic methods. By using the transient electromagnetic method to explore the distribution of high and low resistance bodies in the surrounding area, not only can the geological conditions be grasped, but also the interference caused by metal support in the tunnel can be avoided, the signal-to-noise ratio of the transient electromagnetic signal can be improved, and the drilling cost and workload can be reduced for coal mines. After using individual boreholes for detection, compared to traditional transient electromagnetic methods in tunnels, the "target area" can be more precisely determined, improving detection efficiency.

2. The Principle of Bore-Hole Transient Electromagnetic Method

Bore-hole transient electromagnetic method is used from the mine transient electromagnetic method that applies the ground well transient electromagnetic method to the underground. It is a transient electromagnetic working method that receives transient electromagnetic signals in the borehole and explores changes in physical properties near the borehole. The commonly used methods include single hole transient electromagnetic method and tunnel hole transient

electromagnetic method. Single hole transient electromagnetic method refers to a transient electromagnetic detection method in which the transmitting and receiving devices are both inside the borehole, and both move simultaneously to detect geological anomalies near the borehole; Tunnel transient electromagnetic method refers to a transient electromagnetic detection method in which the transmitting device is located outside the borehole and the receiving device is located inside the borehole to detect geological anomalies near the borehole.

The drilling three-component transient electromagnetic detection technology is based on the basic principle of transient electromagnetic method, which sends the transmitting coil and the three-component receiving coil together into the drilling hole, and conducts three-component measurements point by point. The Z component is along the axial direction of the borehole, and the X and Y components are determined based on the on-site situation. X, Y, and Z form an orthogonal Cartesian coordinate system. By analyzing the spatial orientation of anomalies relative to the borehole through two sets of horizontal component secondary field signals, X and Y, a cylindrical detection area is formed within a certain radial distance range centered on the borehole. The detection schematic is shown in Figure 1.

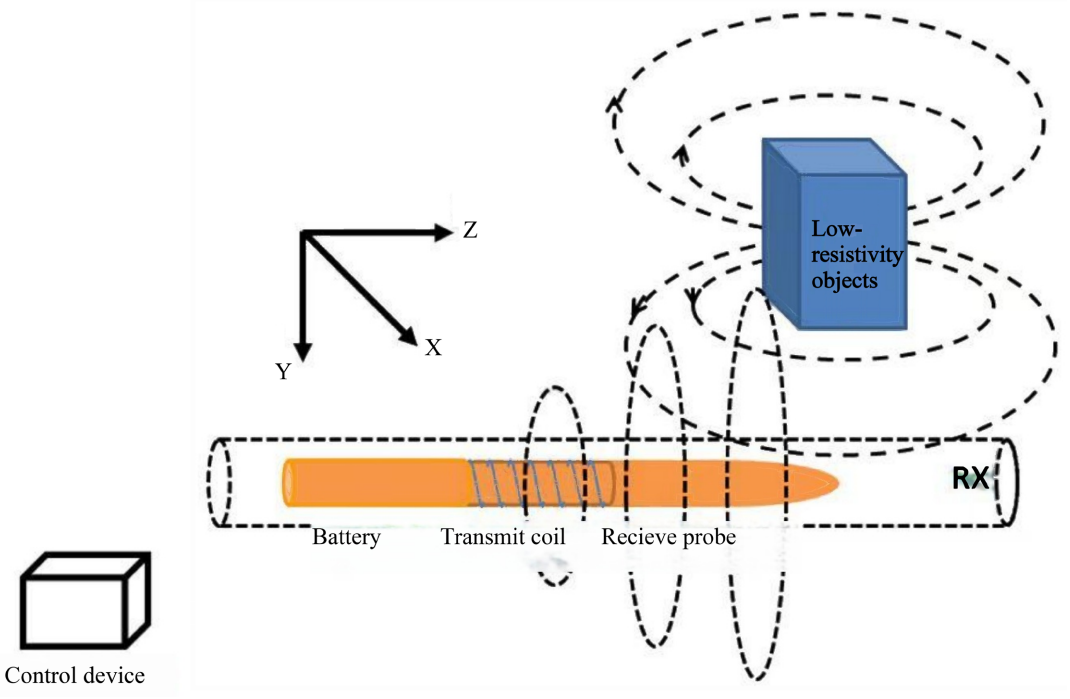

Figure 1. The detection equipment of Bore-hole transient electromagnetic method.

The Bore-hole transient electromagnetic method detection technology is developed based on the basic principles of traditional transient electromagnetic methods. It generally includes a transmitter, receiver, transmitting and receiving antenna, hole synchronization control device, as well as supporting operation software and data interpretation and processing software. The transmitter in-

cludes a transmission circuit and a matching transmission antenna. Its main function is to construct an excitation source for the transient electromagnetic primary field by transmitting bipolar pulse signals. Currently, the transmission waveform of transient electromagnetic equipment in China mainly uses square or trapezoidal waves, and the transmission frequencies mostly include 25 Hz, 12.5 Hz, 6.25 Hz, 2.5 Hz, and other frequencies; The receiver consists of two parts: a high-speed sampling circuit and a receiving antenna. The receiving antenna generally adopts a hollow induction spiral coil or adds a magnetic rod in the middle of the coil to enhance its receiving ability. According to the frequency band and amplitude range of transient electromagnetic signals, the minimum sampling rate of most existing equipment receivers is generally not less than 100 ksps, and the dynamic range is not less than 120 dB.

3. Main Technical Parameters

The performance parameters of the Bore-hole transient electromagnetic method instrument are shown in Table 1.

Table 1. The main technical parameters.

Emission current	4.5 A
Emission voltage	6.5 V
Host transmission frequency	2.5 Hz, 6.25 Hz, 12.5 Hz, 25 Hz
Tracks	2000 tracks
Probe equivalent area	450 m^2
Dynamic range	180 dB
Stacking	10,000
Sampling rates	2 MSPS, 1 MSPS, 0.5 MSPS, 0.25 MSPS, 0.125 MSPS, 0.0625 MSPS
Size	Host 368 * 241 * 163 mm Probe 126 * 118 * 429 mm
Magnification factor	1, 10, 100, 1000 times
Turn off time	0.5 μs
The weight	Host 7 kg Probe 2.5 kg
The dynamic range	130 dB (input frequency 325 Hz)
The power frequency suppression	75 dB (input frequency 50 Hz, 1 V (peak to peak)
Repeated measurement error	0.1% (100 mV peak to peak, 325 Hz sine wave)
Screen	8-inch color LCD display screen

4. The Construction Technology of Bore-Hole Transient Electromagnetic Method Instrument

The data collection process for drilling transient electromagnetic construction is

as follows:

1) After turning on the device and confirming that it is in normal condition, use WiFi wireless communication technology to time and send measurement parameters to the borehole probe;

2) After completing the configuration, connect the probe tube in the hole to the drill pipe and send it into the drilling hole. When pushed to the measurement position by the drilling rig, the probe tube stops and begins to measure and record the orientation and attitude information of the probe tube at the current position. The orifice device records the current measurement time and depth information;

3) After the probe is sent to the bottom of the hole, the detection work is completed. The probe is taken out and the data stored inside the probe in the hole is read back through the hole opening device;

4) Connect the orifice device to the PC, and use the data processing software on the PC to complete the precise processing and interpretation of measurement data.

5. Application

Recently, Xundong Coal Industry in Xunyi County, Shaanxi Province, used the ZDY15000LD directional drilling equipment developed by CCTEG Xi'an Research Institute of China Coal Science and Technology to complete the 1206 m long directional drilling construction along the coal seam under the guidance of technical personnel from Xi'an Research Institute. They also used the YCSZ coal mine Bore-hole transient electromagnetic method technology and equipment developed by Xi'an Research Institute to achieve a long-distance advanced detection of 1026 m in the hole. This is the first time that the mine has used drilling transient electromagnetic technology to achieve ultra-kilometer detection, and also broke the world record for the farthest water hazard advanced detection held by Xi'an Research Institute, marking the maturity and development of the "long excavation and long exploration" water hazard advanced detection technology in coal mines.

After the directional drilling construction was adopted for the 4125 belt groove of Xundong Coal Industry, in order to further explore the water damage situation within the influence range of the proposed excavation tunnel, transient electromagnetic technology and equipment were used to detect the hydrogeological situation 1026 m in front of the groove. Through advanced borehole geophysical exploration, it is expected to save the mining party 33 days of short distance drilling time, more than 3 million yuan in drilling costs, and more than 1.66 million yuan in labor costs. (**Figure 2**)

This is the world record of detection range by using the Bore-hole transient electromagnetic method equipment. Providing a new working method for achieving long-distance and accurate detection of coal mine water hazards, and also providing reliable geological support for the geological transparency of rapid excavation tunnels in coal mines.

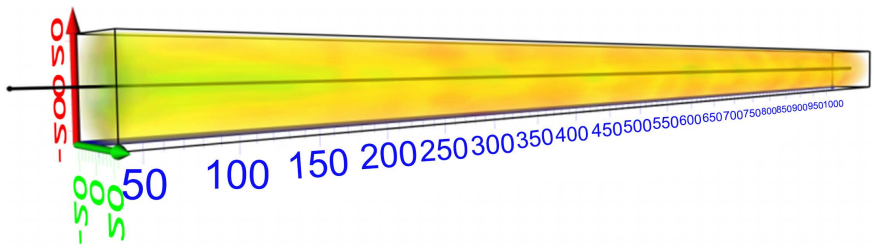

Figure 2. The detection result of YCSZ Bore-hole transient electromagnetic equipment.

6. Conclusions

Based on the theoretical foundation of the full space transient electromagnetic method in coal mines, combined with the actual situation and needs of coal mines underground, this article proposes the transient electromagnetic method in mine holes. The transient electromagnetic exploration is applied to the existing boreholes in coal mines, providing a more effective solution for detecting the geological conditions around the boreholes. Through multiple experiments, it has been proven that the underground transient electromagnetic instrument has a significant effect and accurate results in detecting abnormal water bodies, which is worth promoting and using extensively. The main advantages of this detection method are as follows:

1) The construction is simple, the instruments are easy to carry, the working time is short, and it does not affect the normal production operation of the mine, which can meet the needs of water prevention and control work without affecting production needs.

2) Due to the special support environment underground, metal mesh, anchor rods, and other materials may inevitably affect the instruments. Therefore, it is necessary to minimize the influencing factors. Transient changes in the hole happen to solve this problem to a certain extent.

3) Without the need for special drilling arrangements, sending the receiving probe of the instrument into the existing borehole is not only unaffected by the surrounding environment, but also makes the instrument closer to the anomaly, provides clearer explanations, and makes it easier to determine the location of the anomaly.

4) Reduced the workload of blind drilling by the mining party, saving costs for the mining party.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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