

GPR is Used to Detect and Apply the Fault of the No. 2 Coal Seam of Yuwang Coal Mine

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Abstract

In order to accurately analyze the geological anomalies encountered in the tunnel of coal mine excavation, this paper uses ground penetrating radar to follow up and detect faults in front of coal excavation. Ground penetrating radar is a wide range of survey methods that can quickly cover large areas and locate gaps, while using other invasive methods to locate gaps is difficult and expensive. And the ground penetrating radar can infer details of the location of the fault and the length of the fault. Therefore, the manageability and non-invasive nature of ground penetrating radar makes it particularly suitable for advanced detection in coal mines.

Keywords

GPR; Yuwang Coal Mine; Advanced Detection; Fault.

1. Introduction

Yuwang Coal Mine coal seam buried large depth and complex structural development, the excavation head-on and around the roadway may face the threat to the efficiency and safety of the excavation of structural coal, water, gas protrusion and other disaster sources, it is necessary to carry out the exploration of hidden disaster sources such as mine excavation head-on, coal mining work surface and top floor, and find out the internal structure of the mine, water, gas and other disaster sources and their spatial distribution locations in advance[1-5], and also provide a guarantee for the safe and efficient production of the mine. Ground penetrating radar has the characteristics and advantages of theoretical maturity, simple operation, high resolution, intuitive interpretation results, and no need for auxiliary engineering[6]. Ground-penetrating radar uses the sub-interface reflection wave formed by different dielectric parameters to locate and identify the inside of the detector body and invisible targets, which is widely used in the field of geophysical exploration[5, 7]. This paper conducts a detailed study on the No. 2 coal fault in Yuwang Coal Mine. Therefore, the geological anomalies behind the mining surface can be predicted in advance by ground penetrating radar technology, so as to ensure the safety of coal mining.

2. Detection Principle and Feasibility Analysis

2.1. Basic Principles of Ground Penetrating Radar

Ground penetrating radar consists mainly of a radar host, a radar antenna, a transmission line, and a display[8]. The ground-penetrating radar method is similar to the self-excited and self-

receiving seismic wave reflection method, the ground-penetrating radar emits high-frequency electromagnetic waves through the antenna to the front of the roadway, and reflects through the geological interface, and the receiving antenna receives the radar wave signal and transmits it to the radar host. During the propagation of electromagnetic waves within a medium, changes in the dielectric constant of the medium affect the reflected intensity of the electromagnetic waves [9]. The radar host processes the recorded electromagnetic wave signal. According to the motion characteristics of the received electromagnetic waves, the true structure of the media interface can be judged. Depending on the travel of electromagnetic waves, the position of the interface of the reflective medium can be determined[10].

The distance l positioning of the target body detected by the ground penetrating radar can be calculated by (1):

$$l = vt/2 \quad (1)$$

where v is the propagation speed of the radar wave in the medium; t is the two-way travel time of the radar wave in the medium.

The reflection interface depth H calculation formula is approximated

$$H = \sqrt{v^2 t^2 - x^2} / 2 \quad (2)$$

where x is the distance between the transmit wireless and receive antennas.

For the medium is a coal seam, the speed of the radar wave in the coal seam v can be calculated according to the following equation:

$$v = c/\sqrt{\varepsilon'} \quad (3)$$

Where: c is the propagation speed of light in a vacuum, take 3×10^8 m/s; ε' is the relative dielectric constant of radar waves propagating through the coal seam. The relative dielectric constant of coal does not change much, from lignite coal to anthracite coal is 2.3 to 3.6 [11], and the utilization formula (3) can be derived from v as 0.15 to 0.19 m/ns. Typically, v is usually 0.18 m/ns. According to the theory of electromagnetic fields, the expression of the electric field $E(r)$ of electromagnetic waves in unbounded uniformly depleted media is:

$$E(r) = E_0 e^{\alpha r} e^{j\beta r} \quad (4)$$

where r is the propagation distance of the electromagnetic wave in m; E_0 is the initial signal of the electric field, in unit V/m; α is the attenuation coefficient, in unit Np/m; j is the vector; β is the phase shift coefficient, rad/m. Radar acquisition signals, that is, the electric field signals reflected by radar received by radar $E(r)$, in unit V/m, and the difference in dielectric constants between rock formations and non-coal anomalies provide a reliable geophysical basis for radar to detect anomalies ahead of schedule[12].

2.2. Detection Feasibility Analysis

Yuwang Coal Mine's coal mine underground C₂ coal roof plate is gray-black mudstone and argillaceous siltstone, its surrounding rock strength is weaker than shale, etc., when the roadway excavation advance detection, if you choose to use seismic wave detection technology, drilling method, etc. to carry out detection, no matter which way to cause different degrees of damage to the roadway surrounding rock, cannot ensure that the surrounding rock can always maintain the original state, and even eventually interfere with the quality of the entire mining project. After the use of ground-penetrating radar technology, the 50Mhz high-frequency antenna is conFig.d to effectively control the detection accuracy without causing any damage to the surrounding rock of the roadway. Therefore, the application of yuwang coal mine C₂ coal seam underground has great advantages.

3. Project Examples

3.1. Overview of the Work Area

The total tectonic feature of the mine is a south-east monoclinic, the edge is surrounded by arc-shaped faults, there are secondary broad and gentle folds inside, faults are rare, the formation inclination angle is 6-20°, generally 10-15°, and the local area near the fault can reach 30-43°. A group of near-east-west anticlines developed within the well, showing as a continuous wavy undulating fold group on the profile. The direction of the fault in Ida is mainly north-east, and there are arc-shaped faults that turn from north to east to north and west, mainly distributed near the edge of the well field and near the folds.

The C₂ coal seam in the detection area is a thin to medium thick coal seam with stable layer position, a single structure, occasionally a layer of crust, semi-dark type, medium to sulfur-rich coal, and lump coal. The top plate is mostly gray-black mudstone and argillaceous siltstone, containing pyrite nodules, producing fossils of brachiopods and other animals, which is the lowest layer of changxing step standardized stone in the heterogeneous coal-bearing sedimentation of the Changxing Formation in the old factory mining area. This coal seam is the first locally recoverable coal seam in the wellfield, which is easy to compare. The coal seam top is the boundary between the Longtan Formation and the Changxing Formation.

Detection area 1: The coal mine 1010201 70m head-on in the upper section of the working surface track lane. The roadway is about 5m wide and 2m high, with an arc at the top.

Detection area 2: The coal mine 1010202 the working surface 10102 top pumping alley lower section of the 1190m head-on. The roadway is about 5m wide and 2m high, with an arc at the top.

3.2. Ground Penetrating Radar Data Acquisition

3.2.1. Line Measurement Design

In the head-on palm surface of the roadway, 4 round-trip measurement lines parallel to the bottom plate of the roadway are designed, and a marker point is designed every 0.05m on the measuring line for data positioning, and there are 50 radar data between each two marking points. In the 5m lane wide roadway, a total of 11 marking points is designed for each survey line, and 44 marking points are 2000 radar data for 4 measurement lines. During the data acquisition process, the antenna and the head-on palm surface of the roadway are closely aligned and moved at a uniform speed along the measurement line to ensure the good coupling between the antenna and the palm surface. In the data acquisition, in order to improve the detection accuracy and avoid the impact of random interference on the data, the data will be collected multiple times based on the measurement line, and finally the data will be comprehensively interpreted and analyzed.

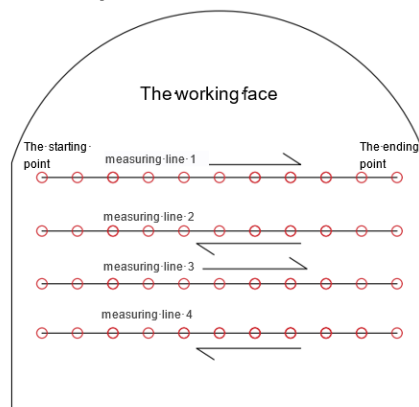


Fig 1. Schematic diagram of radar head-on line survey layout

3.2.2. Acquisition Parameter Settings

Sampling parameters such as sampling frequency and speed of ground penetrating radar will affect the detection effect. Unlike the surface, the environment inside the underground roadway is complex. The actual detection needs to set the radar parameters according to the purpose of the detection and the environmental conditions. For ground-penetrating radar, the antenna with a frequency of 50 MHz has a detection depth of about 50 m. In order to ensure the accuracy of the detection information, the sampling window is set to 200-800 ns, and the number of sampling points is 1024 to control the longitudinal resolution. To highlight the deep signal, manually adjust the appropriate gain.

3.2.3. Precautions for Collection

- (1) Record in detail the influencing factors in the detection environment, such as the nature and location of the surrounding support rods and protective nets, so as to prevent misinterpretation;
- (2) In the process of explosion-proof geological radar movement, it is necessary to mark in time and locate;
- (3) In the collection process, it is necessary to move along the measurement line as close as possible to the working surface at a uniform speed;
- (4) Each set of data collected should be numbered, and the collection parameters, movement direction, sudden interference, etc. should be recorded in detail.

3.3. Probe Data Processing Process

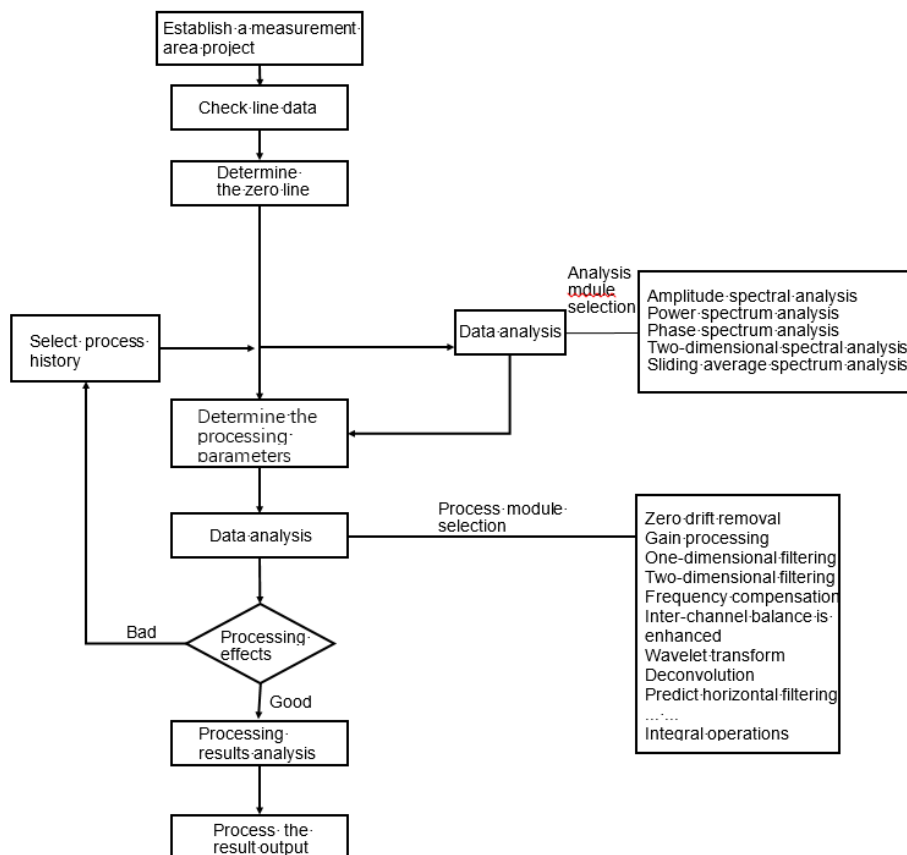


Fig 2. Radar data processing flowchart

The collected ground penetrating radar data needs to be carefully processed by the relevant geological radar software in order to obtain a good detection application effect.

There are many and complex ground-penetrating radar jamming signals, and a variety of methods are required to effectively improve the signal-to-noise ratio, and the processing needs

to be targeted. The basis of radar data processing is digital signal processing, and the main tasks are zero-line correction, one-dimensional filtering, background denoising, gain control, and sliding average[13-15]. In this advanced detection, the ZTR-12 intrinsically safe explosion-proof ground-penetrating radar system was used, equipped with a 50MHz antenna. The process flow is shown in Fig. 2.

3.4. Interpretation of Detection Results

(1) 1010201 detection results of the upper section of the track alley of the working surface
According to the detection data of the 50MHz antenna working surface (Fig. 3), there is an abnormal area 2 to 4m (within the fixed range of the white coil) in front of the working, and comparing the surrounding layers, it can be clearly seen that the abnormal is inverting axis. After analysis, it is speculated that it is a tectonic fault or a joint fracture development of a coal rock layer.

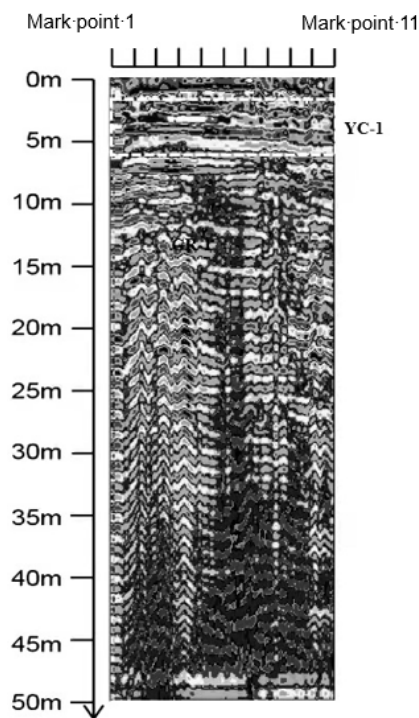


Fig 3. 1010201 head-on radar data processing interpretation profile at 70m in the upper section of the track lane of the working surface

(2) 1010201 detection results of the upper section of the track alley of the working surface
According to the detection data of the working surface of the 50MHz antenna (Fig. 4), there are abnormal areas in the 2-4, 7-10, 11.5-16 and 20.5-25m (within the fixed range of the white coil) in the front of the detection position, and the following analysis can be made in combination with the construction environment and geological data of the site:

- 1) Analysis of coal and rock formation fracture zones and joint development or media changes caused by YC-1 geological structure;
- 2) Analysis of YC-2 shows a set of highly reflective homogeneous axes through the profile, which is speculated to be a change in the medium;
- 3) Analyze the strong radar reflection of YC-3, the in-phase axis fracture and fork, which is a strong fracture zone generated by geological structure;
- 4) Analyze the non-phase axis faults of YC-4 as faults generated by geological formations.

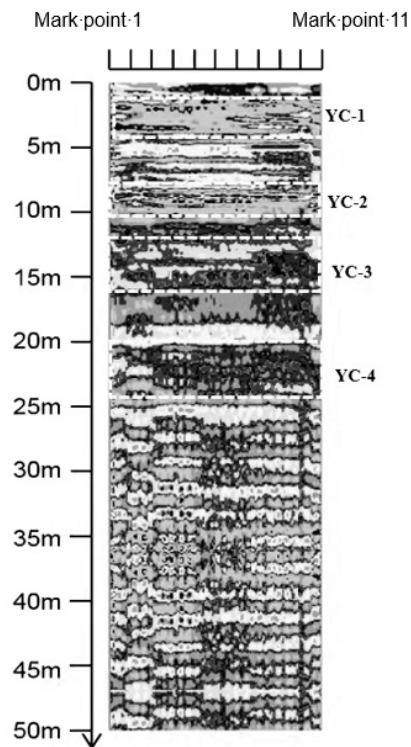


Fig 4. Radar data processing explanatory profile at 1190m in the lower section of the top pumping alley of the working surface

3.5. Verification of Detection Results

Through the actual disclosure of the later project, the location and type of the abnormal area are basically consistent. The disclosure is as follows:

- (1) 1010201 the upper section of the working surface track alley: a positive fault is exposed at a mileage of $K_0+75.6m$
- (2) The lower section of the 10102 working surface roof pumping alleys: the lithology changes from sandstone to mudstone at the mileage of $K_0+1194m$, the rock mass at $K_0+1195m$ is seriously broken, and the $K_0+1198.3m$ reveals a positive fault.

Under the conditions of Yuwang Coal Mine, the effective distance of coal seam detection can reach 50m. The success rate of the detection test has also reached 80%.

4. Summary

(1) Ground penetrating radar technology is feasible in principle for detecting the fault in the No. 2 coal of Yuwang Coal Mine, and has achieved good results in actual operation, and obtained high-quality images that clearly reflect the location and depth of the fault. The portable, fast, accurate, non-destructive and intuitive image characteristics of ground penetrating radar in detection, especially the ability of ground penetrating radar to work under harsh working conditions, will make it more and more important in the field of geological exploration.

(2) This study adopts the ZTR-12 intrinsically safe explosion-proof ground-penetrating radar system, equipped with a main frequency of 50MHz antenna, which has certain advantages in detection depth and resolution, and its detection data can not only determine the location of the fault, but also clearly reflect and distinguish the interface of different shallow media to meet the needs of surface geological structure investigation.

(3) The ground penetrating radar detection data reflects the image of the continuous underground profile, which can greatly supplement the lack of drilling data, and the combination of the two means is more conducive to clarifying the geological structure between

the coal seams. Therefore, this data should be analyzed in detail, combined with other detection methods and known geological data, so as to provide accurate prediction results.

Acknowledgments

This work was supported in part by the Research and Application Project on Comprehensive Geophysical Exploration of Mine Geophysics of Geological Disaster Sources in Huaneng East Yunnan Mining Area (HNKJ20H35), in part by the National Natural Science Fund of China under Grant (52074306), and in part by the National Key Research and Development Program of China under Grant (2019YFC1805504).

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