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Advanced Predication of Geological anomalous Body Ahead of
Laneway Using Seismic Tomography Technique

Junlong Shang^a, Xianwei Luo^{a,b}, Feng Gao^a, Jianhua Hu^{a,*}, Keping Zhou^a

^a*School of Resources and Safety Engineering, Central South University, Changsha, 410083, China*

^b*Tongkeng Mine, Liuzhou Tin Group Company Ltd, Hechi, 545000, China*

Abstract

Advanced predication of geological anomalous body (GAB) of laneway can provide scientific references for mine safety production. It refers to reveal the position, shape and size of GAB in advance. Seismic tomography technology (STT) can realize the prediction of GAB using tunnel surface waves. Tunnel Reflection Tomography (TRT) 6000 system, which is on the basis of STT, has the advantages of convenience and high reliability. In this paper, TRT6000 is introduced to forecast the GAB ahead of laneway in underground metal mine. The operation steps, data processing and notes about TRT6000 are detailed. The research results show that there are two water flowing fractures, separately located at around 50meters and 85meters ahead of laneway. And the prediction results match the actual situation well. Therefore, the seismic tomography technology improves the mine safety management, and the TRT6000 provides a new method for predicting GAB in advance.

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Keywords: Seismic tomography, Geological anomalous body, Advanced predication, Tunnel reflection tomography system

Introduction

During the actual processes of construction in underground engineering, water burstings and collapses will threaten the property and the security of peoples' life because of inaccurate geological materials [1]. And the existing of water-bearing structure (including goaf, karst cave and water flowing fracture), weak structural plane and fault ahead of laneway may lead to many engineering disasters. Advanced geological detection refers to the forecast and analysis of the feature and position of the geological anomalous body (GAB) ahead of laneway in advance. It can provide guidance for engineering design and construction, so as to reduce the accidents and improve safety production in metal mines.

Because of complexibility and changeability of the environment in underground mine, it is difficult to predict the GAB. At present, the predicting technique mainly classified as loss prediction and lossless prediction. The loss prediction methods such as advanced guide hole method and advanced heading method, are usually time and labor consuming and would severely influence project procedures [2-3]. With the development of technology, the lossless prediction method is widely used to predict the GAB for its convenience and reliability. And common lossless methods including landsonar method [4], tunnel seismic probe method (TSP) [5], GPR method [6] and high density resistivity method [7], share these advantages, but

* Jian-hua Hu. Tel.: +86-731-88879965.

E-mail address: hujh21@csu.edu.cn.

have their limitations as well. For example, the establishment of forward images using the landsonar method relies on the geological condition heavily, therefore the geological condition must be known in advance. TSP method may affect the engineering process and the seismic source used in blasting is usually hidden trouble in safety. GPR method requires high smoothness of ground and the operating process is more complicated. The prospecting effect by using high density resistivity method is impacted by external environment (including conductivity and dielectric constant) greatly. In a word, the existing lossless detecting methods don't completely eliminate the harmful geological problems.

Seismic tomography technology (STT) started in the late 1980s, and had been widely used in the sphere of the structure of the interior of the earth imaging, oil exploration [8], underground metal mining [9,10] and engineering disaster predicting [11], etc. The principle of STT is that part of the signals will be reflected back and another part of the signal will enter into the medium in front when the seismic waves encounter the differences in acoustic impedance. After being analyzed, the signal will be used to help to know the location and size of GAB ahead of laneway [12].

Tunnel Reflection Tomography (TRT) 6000, which is on the basis of STT, is a very high productive tool for the GAB prediction in advance [13]. In this paper, TRT6000 is introduced to predict the GAB ahead of laneway in underground metal mine, the objective is to provide theoretical guidance for the design and construction of laneway in underground mine, thus reducing engineering disasters to the greatest extent and guaranteeing the continued safe and efficient production of the mine.

1. Seismic tomography technique

1.1. Seismic reflection wave principle

According to seismic reflection wave principle, part of seismic wave will be reflected back when the seismic waves encounter the GAB, such as fault, fracture zone and water flowing fracture, etc. And the reflection coefficient can be calculated according to the following formula:

$$R = \frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1} \quad (1)$$

Where R denotes the reflection coefficient, ρ_1 and ρ_2 stand for the rock stratum density, V_1 and V_2 are equal to the velocity when the seismic wave transmits in the rock.

The reflection coefficient value is greater than 0 when seismic reflection wave transmits from low wave impedance medium to higher one, vice versa, less than 0. Reflection waves' polarity may be inconsistent with the wave source if there exists GAB in rock mass, the bigger the GAB, the greater the difference. So we predict the position and other natures of the GAB

1.2. Three-dimensional seismic tomography principle

According to the seismic tomography principle, reflection signals can be obtained by receivers when the seismic wave across GAB. And ellipse can be determined by the source and receiver. If there are enough receivers, the accurate position of the reflection point on the GAB can be known by intersecting the ellipses. At last, the accurate three-dimensional image of GAB can be determined by overlapping the reflection points on the GAB [14-15]. The principle of seismic tomography is shown in Fig.1.

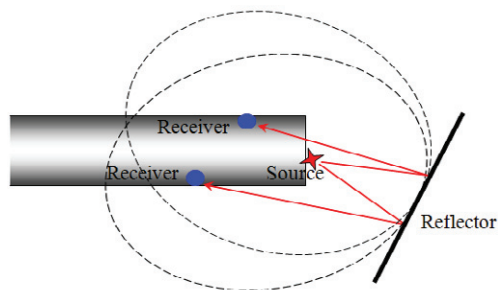


Fig.1. Principle of seismic tomography

1.3. Tunnel reflection tomography 6000 system

Tunnel Reflection Tomography 6000 (TRT6000), a system produced by the United States C-Thru company, is used to predict the GAB in advance. And the system consists of host, base station, wireless module and trigger hammer (Fig.2).

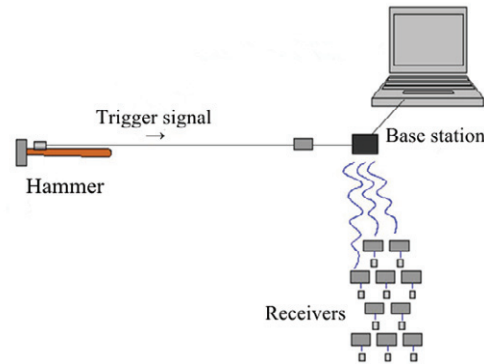


Fig.2. Sketch of TRT6000 system

(1) Data collection

According to the seismic tomography principle, there are 12 sources and 10 wireless modules arranged in the laneway (in Fig.3), and the array pitches are 2m and 5m respectively. The distance between the end line of the sources and the first line of receivers reaches 10m to 20m. In order to eliminate the data errors, we beat each source point 3 times using the hammer with sensor. The seismic waves generated by the hammer will spread in surrounding rocks, and wireless modules can obtain the seismic signals and transmit the signals to the base station computer. The arrangement of the resources and wireless modules is shown in Fig.3.

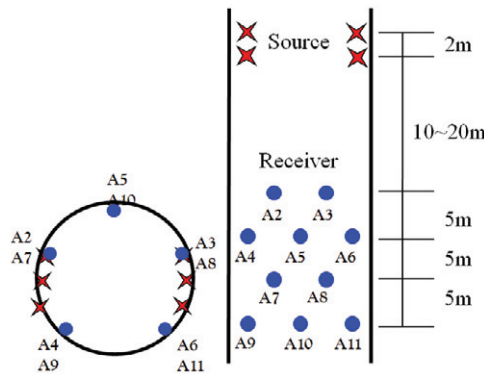


Fig.3. Resources and wireless modules arrangement

(2) Data processing

TRT6000 data processing procedure contains the following steps:

- Obtain coordinates: three dimensional coordinates of 12 sources, 10 wireless modules, central points of the excavating face and end of laneway are necessary in order to accurately predict the position of the GAB ahead of laneway;
- Filter noise signals: in general, the blasting vibration around and some other irregular vibrations way influent the accuracy of the prediction. TRT6000 has its own filter that can be used to get the clear signals;

- Separate P wave and S wave: P wave stands for compression wave, and S wave stands for extension wave;
- Process image: extracting the reflective surface and calculating the reflection coefficient and velocity;
- Output result: on the above steps, the geological conditions can be shown in the 3D image window.

2. Engineering case study

2.1. Engineering profile

Tongkeng Mine of Huaxi Group is a typical underground metal mine, and the annual output of raw ores has exceeded 2million tons. Up to date, the 92# deposit is the main mining ore body, and it is controlled by the facture, which belongs to part of the north east extension of cross-tension faults in Dachang town. The geological condition underground is too much complex. In order to guarantee the security of staff and maintain the normal production, TRT6000 is introduced to predict GAB ahead of laneway at 531m level.

2.2. Data collection and processing

After determining the test site, we can arrange the 10sensors and 12 sources according to the principles of TRT6000. In order to obtain effective signals, it is necessary to select the even rock surface in laneway to guarantee the good coupling between sensor and rock surface. The installation state of sensor 8 is shown in Fig.4.

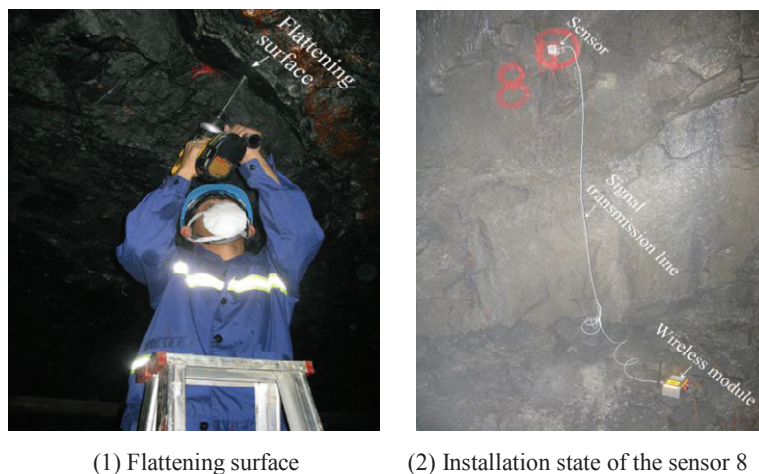


Fig.4. Sketches of the sensor installation

The seismic waves are achieved by hammering the source points separately, at the same time the base station can receive the seismic signals. Then the 3D laneway in the detection range can be established using the three dimensions of the sources and wireless modules which are obtained by the full automatic control station. In order to eliminate the noise in the signals, the first arrive time of wave crest or wave trough in the 10 channels should be chosen out.

According to the actual situation, the detecting range of TRT6000 is confined to 110m ahead of working face. On the other hand, though the conduct inverse calculation, the average velocity of longitudinal wave for the surrounding rock V_p is equal to 3000m/s and the average velocity of transverse wave for the surrounding rock V_s is equal to 1800m/s. It is shown in Fig.5.

2.3. Results analysis

By analyzing we can see that: reflectors barely exist within 30 meters of the working face for that the reflective energy is relatively weak. So there is no geological anomalous body in this region and we have given the integrity of the rock mass in this

region a verdict of satisfactory. There are some weaker reflectors in the range of 30~40 meters of the working face. In the meantime, the reflector coefficients are mainly negative. It is easy to see that the integrity of rock mass in this region is relatively poor. And it is in absence of a large fracture zone. In the range of 40~110 meters in front of the working face, the background values are comparatively weak and the reflector coefficients are all negative. At same time, the negative reflective energy is strong which prove that the rock mass in this region is broken desperately. Meanwhile, at around 50 meters and 85 meters, there

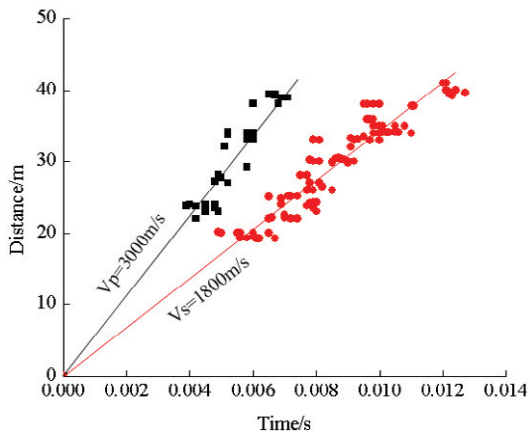


Fig.5. Inversion chart of the average wave velocity

are two steep reflectors with angles of 70 degree. It is inferred that the two steep reflectors belong to large-size fractures as that the negative reflective energy is extremely strong and the reflectors run through the image zone. So it may cause engineering disaster such as collapse and flood when the laneway is excavated in this region. The prediction results are shown in Fig.6.

According to the actual situation, it is known that the rock in the range of 50~100 meters is severely cracked ahead of laneway, accompanied with the phenomenon of water flood. And two major water flowing fractures are clearly visible in Fig.7 (2). It is proved by practical situation that the advanced prediction results of GAB ahead of laneway in this paper are scientifically reasonable.

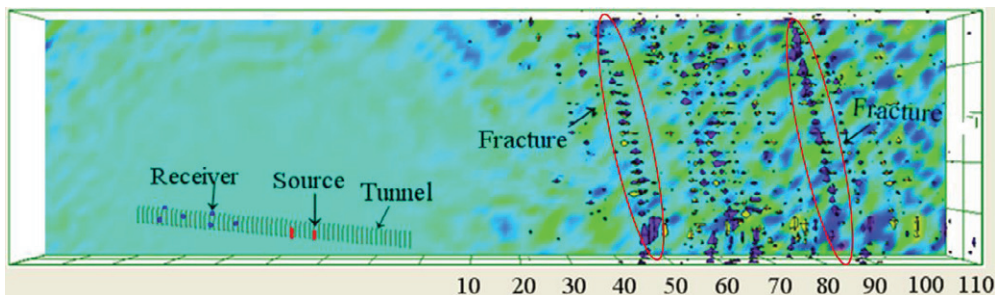


Fig.6. predication results of GAB ahead of laneway



(1) Fissure rock mass

(2) Water flowing fractures

Fig.7. actual situation

Conclusions

Based on the principle of seismic tomography, TRT6000 system is introduced to the prediction of geological anomalous body ahead of laneway in underground metal mine. Several conclusions have been achieved in this study:

(1) Seismic tomography technology can position geological anomalous body ahead of laneway using multigroup ellipsoids, and it has the advantages of high reliability and precision;

(2) TRT6000 system, which is on the basis of the seismic tomography technology, has the capability for detection at long distances. And the method is proved to be simple in operation, reliable and visual vivacious in results, and can be used as an important measure to predict GAB. At the same time, by taking the hammering as seismic source, it has the advantages over other lossless prediction methods in being safe and low-cost;

(3) Taking the Tongkeng underground metal mine of Huaxi Group in China as an example, we have predicted GAB ahead of laneway in advance. The results agree well with the actual situation, and offering guidance for safety production and the design and construction of laneway.

(4) A more accurate prediction result would be achieved if it was used combined with some other shorter detection methods, such as Ground Penetrating Radar.

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