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Application of Radon Transform in in-seam Wave Advanced Detection Technology

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ABSTRACT

In view of the increasingly high degree of mechanization of coal mining and the increasing difficulty of mining, seismic exploration based on ground seismic method is not applicable in coal seams. Therefore, a trough wave seismic detection method of geophysical prospecting method is introduced into coal mine tunneling roadway, which provides a method and means for ascertaining the geological anomalies in front of the tunnel face. Combined with modern geological information, seismic data can be visualized and interpreted by geological personnel, which can identify geological anomalies such as faults, collapse columns, goafs and water inrush areas in the process of coal seam excavation and mining, and reduce the occurrence of disasters and accidents in the mining process.

KEYWORDS

Coal seam; channel wave; visualization; fault.

1. INTRODUCTION

Although China's energy structure began to diversify, but the proportion of coal in China's energy consumption occupies a large part, or the main energy supply[1]. In contrast, more and more coal is mined, and the difficulty of coal mining becomes greater, and more and more accidents occur in the mining process[2]. Mine accidents often occur in the process of coal mining, and the cause of mine accidents is that the understanding of the internal structure of coal seam is not clear enough, the existence of faults in coal seam may lead to coal and gas outburst accidents, the existence of collapse columns may lead to water inrush accidents in the mining process, and the change of coal seam thickness will increase the difficulty of mining. Therefore, in order to reduce the occurrence of mine accidents and improve the mining efficiency of coal seam, it has become a major event to find out the internal structure of coal seam.

There are many methods for the exploration of underground abnormal bodies, among which seismic exploration in geophysical exploration is gradually used as a conventional exploration means because of its advantages of high detection accuracy, low cost and convenient detection. For small structures and coal seams with long detection distance, it is more suitable for in-seam seismic exploration, and the distance of in-seam exploration can reach about 300 in front of the working face and maintain a high accuracy[3]. The principle that seismic waves reflect when they encounter discontinuities provides a theoretical basis for in-seam exploration of faults in coal seams.

2. PRINCIPLE OF IN-SEAM SEISMIC REFLECTION METHOD

The in-seam seismic prospecting method is to excite the in-seam wave in coal seam by explosive source or hammering source, and record two horizontal vibration components simultaneously with two component detectors: one component is perpendicular to the coal wall; The other component is parallel to the coal wall. The in-seam seismometer is similar to the ground digital seismometer, but it is explosion-proof, has a higher upper frequency, and is more portable.

There are two basic measurement methods of in-seam seismic exploration: transmitted wave method and reflected wave method. In the transmission wave method, the source and detector are placed in different roadway (including borehole, working face, etc.). In the reflection wave method, the source and the geophone are placed in the same roadway, which is similar to the ground seismic survey. Common reflection point multiple superposition technique is often used.

If there is a fault with a drop greater than the thickness of coal in the mining area, the fault will completely block the waveguide, and there will be reflection without transmission of trough wave. If the fault drop is less than the coal thickness and the waveguide is partially blocked, part of the energy is reflected and part of the energy forms a transmitted trough wave. According to the presence and strength of reflected and transmitted in-seam waves, we can judge whether there is any anomaly in the measuring area and the degree of blocking.

Because the density and velocity of the coal seam are lower than that of the surrounding rock, strong wave impedance will be formed at the upper and lower interfaces of the coal seam[4]. When the seismic wave is excited in the coal seam, the seismic wave will propagate in the direction of the surrounding rock, and the distance from the focal point will form a projection, and the wave leakage will occur. When the incidence Angle reaches a certain Angle, the seismic wave will be reflected and refracted at the interface of strong wave impedance, and form a gliding wave in the surrounding rock, which travels for a certain distance and returns to the coal seam to form a total reflection. All kinds of waves in the coal seam superimpose each other to form guided waves propagating along the coal seam called trough waves.

At the front of the roadway near the position of the cut eye, the detection point is arranged behind, and the observation system of one shot and more harvest is adopted. When the seismic wave meets the fault in front of the source, the seismic wave will be reflected, and the reflected signal is received at the detector in the rear. According to the arrival time of the wave and the distance between the source and the detector, the position of the fault is located in front of the tangent[5].

Trough wave is a kind of wave propagating in coal seam, which is formed by total reflection between surrounding rock and coal seam, so the petrophysical parameters of surrounding rock and coal seam have an influence on the characteristics of trough wave. The most important characteristic of the in-seam wave is the dispersion, that is, the velocity of the in-seam wave changes with the frequency of the source. There are two kinds of in-seam velocity, group velocity and phase velocity. The minimum value of the group velocity is the Airy phase velocity of the in-slot wave, and the phase velocity is the velocity of the seismic wave at a certain frequency. The dispersion of the in-seam wave is affected by the physical properties of the surrounding rock and the thickness of the coal seam, but the Airy phase of the in-seam wave is a fixed value, and the structure in the coal seam can be detected by the travel time of the Airy phase of the in-seam wave[6].

3. EXTRACTION OF REFLECTED WAVES

3.1. Observation method

Single-channel continuous section method and multi-channel continuous section method are mainly used. In order to improve the signal-to-noise ratio, common deep point reflection technology is also widely used in multi-channel continuous section method.

(1) Single channel continuous section method

Also known as continuous seabed reflection seismic profiling, it is a high-resolution reflection wave method mainly used to understand the seabed topography, shallow loose deposits and basement conditions. The single-channel continuous profiling method mainly uses the electric spark as the focal point, and sometimes also uses the electromagnetic pulse or air gun. At work, the observation ship tows the receiving section of a seismic recording track along the design survey line for constant speed, so that the source for equal time or equal distance excitation, by the receiving section to receive reflected seismic waves, with mechanical or photographic devices to record and display directly. This kind of observation is economical and efficient.

(2) Multichannel continuous profiling

Used for regional geological survey, especially offshore oil and gas resources survey. The seismic multi-channel combination receiving device should be placed at the optimal receiving depth in the water and in a neutral and equal floating state, and the combined air gun should be sunk at the optimal excitation depth in the water from one or both sides of the stern. The observation ship travels along the measurement line at a speed of about 5 knots, and the combined air gun is excited once every certain distance (or time) traveled. The seismic waves generated penetrate the seabed strata, and are reflected back to the seawater layer at different interfaces. The seismic waves are received by the multi-channel floating receiving device, and then amplified, sampled, gained control, analog to digital conversion and recorded on the tape. Thus, a covering observation of the seabed reflection interface is completed. The multi-channel continuous profile method requires the observation ship to sail continuously on the survey line and successively excite and obtain the seismic data covering the reflection interface continuously.

(3) Common deep point reflection

In the work of Marine seismic reflection multi-channel profiling method, in order to improve the energy of reflected waves and suppress the interference in seismic observation (especially multiple reflections), improve its reliability and accuracy, multiple coverage technology is generally used, called common deep point reflection, also known as common deep point horizontal superposition. It is required to shorten the source excitation distance and increase the excitation times on the basis of one coverage observation system to realize multiple coverage observation of the seabed reflection interface. After data collection, different source locations are analyzed. The records of different receiving segments of the same reflection point (CDP-1) information are added together to obtain multiple overlay data of the reflection point, that is, multiple overlay records. According to the principle of superposition, the signal with common reflection points is strengthened by multiple overlay technology, and other interference is suppressed, thus improving the quality of reflection seismic data acquisition. The common deep point reflection technique requires accurate knowledge of the location of the source at the time of excitation. Therefore, most of the modern Marine seismic exploration ships connect the navigation and positioning system with the source and seismometer, and realize the coordination and control of their work through the electronic computer.

In recent years, three-dimensional seismic observation has been carried out on the basis of multi-channel section observation, so that the source and the receiving point are in the same area, and the observation data of the common deep point reflection are obtained successively. The line density and the excitation number of the source are very large, which can provide accurate structural maps, improve the drilling accuracy, and can understand the internal situation of the basement, providing more abundant geological data for oil and gas exploration.

3.2. Extraction method

It is easy to distinguish the types of waves in the seismic section, but there will be interference between some waves. In order to improve the signal-to-noise ratio, it is necessary to separate the reflected waves of the trough wave in the seismic section. The purpose of spectrum analysis is to determine the frequency band range of the in-seam wave reflection wave, determine the frequency band range of the seismic crossbar wave, direct wave and reflected wave, and then carry out digital filtering for the in-seam wave reflection wave to extract the effective wave. There are two methods to extract the finite wave, one is f-k filter, the other is τ-p[7], both of which can extract the reflected wave of the slot wave. The reflection wave is extracted mainly by τ-p filter, which can remove the direct wave well. The basic principle of this method is to sum the signals in the t-x domain along a line with a fixed slope p and an intercept τ. The direct wave is filtered out by using the different apparent velocity between the direct wave and the reflected wave, the reflected wave is extracted, the signal-to-noise ratio is improved, and the accuracy of the interpretation of the geological section is improved.

4. SEISMIC DATA INFORMATION

After the observation system of coal seam roadway is installed, seismic waves are excited in the mine, received in the geophone, the seismic data is recorded, and the data is saved in excel after being sorted out by geological personnel. A total of 32 actual seismic data were selected, and one of them was selected for data analysis. For example, the spectrum diagram of the first data is selected after matlab analysised.As shown in Figure 1.a is the original seismic record, b is the unilateral amplitude-frequency response recorded by the channel model, c is the bilateral amplitude-frequency response, and d is the phase spectrum.

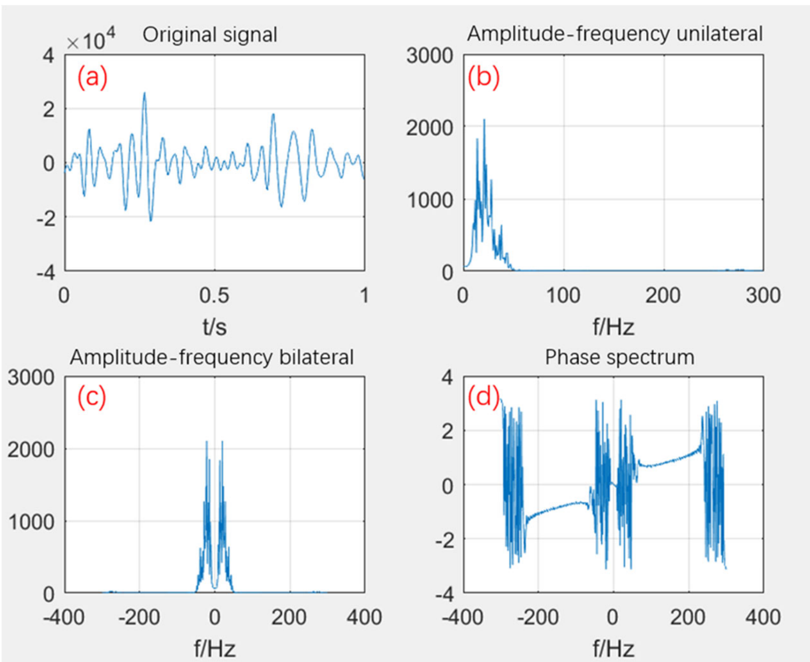

Figure 1. Spectrogram

5. RADON TRANSFORMATION

5.1. Radon transformation principle

Radon transform is the key of τ-p domain filtering. The seismic reflection wave can be obtained by removing the interference wave from the seismic wave. Because there is only time t and seismic signal in the actual seismic record, and there is a certain distance between the source and the detector for offset x, so we get the seismic record is t-x domain, there is no way to remove the interference wave, so it needs to be converted to the τ-p domain. The principle of Radon transformation is to sum the signal in the t-x domain along the fixed slope p and the linear superposition of the intercept τ, so the τ-p transformation is also called the tilt superposition, and the physical meaning of p and τ is 1/v and zero gun-spacing time respectively.

5.2. The principle and characteristics of filtering

Let the two-dimensional signal in the domain be (t-x), and the two-dimensional signal after conversion to the (τ-p) domain be $\phi(\tau \cdot p)$, Then there is the positive and negative transformation relation of τ-p:

$$\phi(\tau, P) = \int_{-\infty}^{+\infty} \psi(t, x)\, dx = \int_{-\infty}^{+\infty} \psi(\tau + Px, x)\, dx. \quad (1)$$

$$\psi(t, x) = \frac{1}{2\pi}\frac{\partial}{\partial t}\int_{-\infty}^{+\infty} H^{+}[\phi(\tau \cdot P)]\, dp = \frac{-1}{2\pi}\frac{\partial}{\partial t} H \int_{-\infty}^{+\infty} \phi(t - px, P)\, dP. \quad (2)$$

Where H^{+} represents the Hilbert transform of the function $\phi(\tau, p)$. A straight line in the (t-x) domain becomes a point when converted to the (τ-p) domain, and a hyperbola becomes an elliptic arc when converted to the (τ-p) domain.As shown in Figure 2.

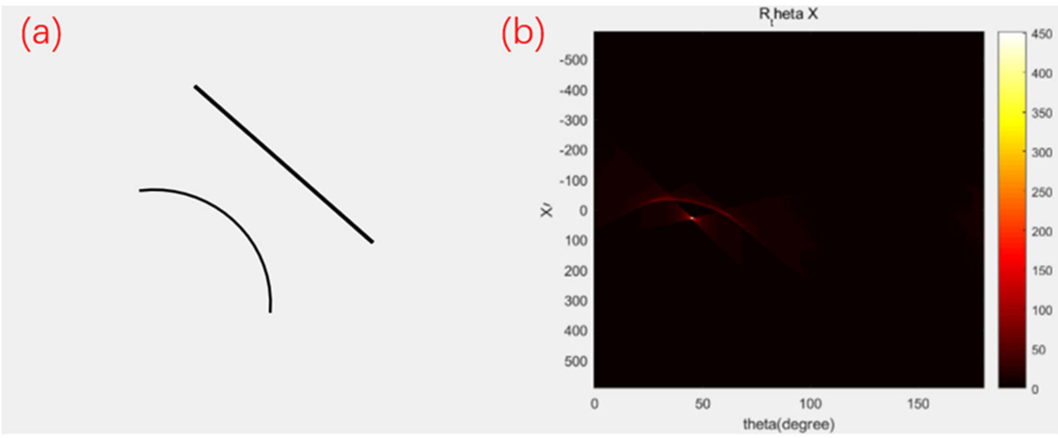

Figure 2. Radon transform

6. RESULTS INTERPRETATION BASIS

Many seismic wave signals can be received in the geophone, including in-seam direct wave, in-seam reflected wave, seismic longitudinal wave, seismic shear wave and so on. Seismic wave attributes carry a lot of relevant geological information, each seismic wave attributes are different, we can analyze the geological structure in front of the palm face of coal seam roadway by analyzing the seismic attributes of the in-seam wave reflection wave.

The velocity of the seismic wave is larger than that of the in-seam wave, so it is easier to distinguish the in-seam wave from the seismic wave in the geological section. The in-seam direct wave is a kind of seismic wave that is excited in the coal seam and propagates directly along the coal seam to the geophone to be received by the geophone, while the in-seam reflected wave is the seismic wave that propagates from the source to the fault in front of the palm plane after being excited by the source, and then reflects back to the geophone to be received by the geophone through the fault plane. In-seam reflected wave and in-seam direct wave are easier to distinguish, because in-seam direct wave is first received by the detector, and in-seam reflected wave is then received by the detector, and the reception of the two waves can be distinguished on the seismic profile with a certain time interval. Then the seismic properties[8] such as amplitude and phase of seismic waves are analyzed to make geological interpretation of faults.

7. CONCLUSION

1. This paper discusses the application of in-seam seismic exploration to coal seam, which can detect geological anomalies in front of the palm face, make the internal structure of coal seam transparent, and reduce the occurrence of disasters in the mining process.

2. Combined with actual seismic data, modern geological information and interpretation by geologists, the seismic data can be visualized into geological anomalies in actual coal mines, which greatly improves the efficiency of coal seam mining.

3. radon transform is introduced, which solves the filtering function in many seismic waves, extracts the effective seismic waves we need, and filters the interference waves.

4. Trough wave seismic exploration in coal seam to detect geological anomalies, the accuracy can not reach 100%, but also need to combine drilling and other technical means, in advance detection still need the majority of geologists in-depth research.

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