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Analysis of High-Resolution Seismic Exploration in Coalfield Geological Exploration Methods

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Abstract: *In the field of coalfield geological research, the era of traditional geological research has basically ended. At present, it is in the period of earth system scientific research. Starting from the main factors affecting high-resolution seismic exploration and combining with some examples of high-resolution seismic exploration in coal exploration,.this paper analyzes and discusses the middle and high-resolution seismic exploration methods in coal exploration, mainly discusses several key links of high-resolution seismic exploration in the field data acquisition process, and makes a brief summary and induction of seismic wave excitation, seismic wave reception, demonstration of acquisition methods and noise suppression.*

Keywords: *Seismic wave, Geophone combination, High resolution, Coal exploration, Geological exploration*

1. Introduction

In recent years, the economic losses caused by coalfield accidents are staggering. In the final analysis, it's all due to the ignorance of underground stratum structure and fault development. Coal seismic exploration is different from petroleum seismic exploration, and oilfield development needs to obtain the distribution of 3 ~ 5m thick sand bodies and the development of faults with a drop of less than 5m. However, seismic exploration in coalfields is mainly in shallow layer, and most of them are located in the wing of syncline, with complex structure and developed igneous rock, which makes exploration difficult. With the deepening of coal field development, at the same time, with the increasing degree of mechanical mining, the stability and continuity of coal seam and the proven degree of small faults near coal seam are required to be higher. Therefore, the research work of seismic exploration has changed from macro-exploration to micro-exploration to "micro-structure" exploration and thin-layer research, and high-resolution seismic exploration has become the best choice. High-resolution seismic exploration can not only effectively solve the small faults and structural details that can't be controlled by drilling, but also solve the zoom area of coal seam washout area and some small geological problems that can't be distinguished by simulated earthquake and drilling data. Moreover, its short period and cost are far lower than that of drilling and 3D seismic exploration, which has more advantages than conventional seismic exploration in identifying small structures, small faults and distinguishing thin strata. Of course, other factors should be considered in high-resolution data acquisition, such as adopting appropriate spatial and temporal sampling rates and selecting appropriate coverage times. Because these factors have been discussed in detail in the past literature, I will not repeat them here. In short, using high-resolution seismic exploration instead of traditional exploration methods in coalfield geological exploration can reduce the cost, time and risk. So today, we will make a brief analysis of the method of high-resolution seismic exploration in coalfield geological exploration.

2. Excitation of seismic waves

The seismic source is the main factor affecting the data resolution. The wavelet generated by the seismic source excited by high-resolution seismic exploration should meet the following conditions: high frequency band, high main frequency and high signal-to-noise ratio. Geophysical workers in the field have done a lot of experimental work around how to improve the "three highs" and summed up many valuable experiences. In order to obtain high-frequency reflected waves, the source must excite high-frequency pulses, and there are two ways to improve the excitation frequency. Small dosage can excite high-energy pulse for more than 50 weeks. If excited in a well below the water table, the

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following points can be known.

(1) The duration and amplitude of the pulse are proportional to M/3.

(2) The absolute spectrum width of the pulse is inversely proportional to M/3.

(3) The duration of pulse is inversely proportional to its frequency band

(4) The formula of frequency is t = 1/f. That is, α=KM/3.

K is the coefficient related to the chemical properties of illumination and the physical properties of medium. Therefore, a small dose can widen the pulse spectrum and reduce the extension, so the frequency can be increased. In order to improve the resolution, we mostly use the excitation method of small dose, because from the excitation spectrum, small dose can excite high-frequency components with a high proportion, which is beneficial to improve the resolution. The same conclusion can be obtained by increasing the dosage in low frequency band (below 50Hz), but in high frequency band, the content of high frequency components has increased instead of decreasing. The relatively high-frequency information can be obtained by low-dose stimulation, but the energy is insufficient, and the best way to overcome the energy shortage is to use low-dose combination well stimulation. There are many factors that affect the generation and propagation of explosion seismic waves. However, these factors can always be attributed to three aspects: explosion source, transmission medium and transmission path.

Relatively speaking, the influence law of explosion source is complex, which is closely related to the generation of explosion seismic waves. Due to the complexity of geological conditions and the limitation of experimental testing and data processing methods, the physical properties and influence of the occurrence process in this area are only partially known at present. At present, the research on the factors affecting the excitation effect of explosive source mainly focuses on the influence of explosive quantity, buried depth, different explosive types and different charge structures on the seismic wave field generated by explosive source explosion. Large dosage has obvious effect on enhancing the deep reflection signal of low frequency, and also has certain effect on enhancing the weak signal of deep high frequency. However, the effect of increasing dosage to enhance high frequency is limited, and it is necessary to take measures to enhance high frequency at the same time of increasing dosage. In seismic exploration, apart from the energy of seismic waves, another key point is the main frequency of seismic waves, which directly affects the resolution of seismic waves and the accuracy of seismic exploration. As the definition of the main frequency of seismic wave is various and each has its own advantages, in view of the fact that there are many peaks of seismic wave spectrum measured in this experiment, the frequency value of the calculation interval after the amplitude of 0.7 times is found through the spectrum diagram obtained after FFT transformation. The specific calculation diagram is shown in Figure 1 below.

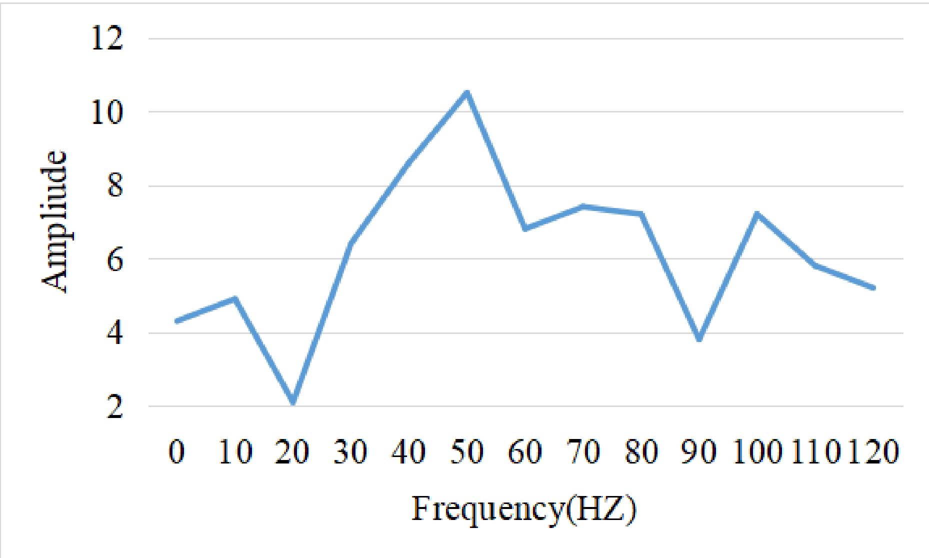

Figure 1: Schematic diagram of main frequency calculation

In a work area, the above high-resolution seismic exploration and acquisition technology has been adopted, and good geological results have been achieved. Field acquisition construction method:

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combination excitation of three wells, area combination of four downhole geophones, and downhole depth of 0.5m Fig. 1 shows that using the above acquisition technology series, the single shot recording has achieved such an effect: after the frequency scanning of 90~ 150 Hz, the reflection layer can still see a clear coaxial axis. The acquisition technology of high-resolution seismic exploration is still a permanent research topic.

3. Blem of geophone combination

A geophone is a receiver for picking up the earth vibration, which is mainly composed of a coil, a permanent magnet, a spring leaf and a shell.

3.1. Can single point acceptance replace detection wave combination

It is a transducing device for converting the mechanical vibration of ground particles into electrical signals. According to different uses, geophones are divided into P-wave geophones, S-wave geophones and three-component geophones. Seismograph is a device for collecting seismic data in the field, which is mainly composed of geophone, amplifier, digital recorder and microcomputer. Besides receiving and recording seismic waves, it can also monitor the quality of the collected data and make simple preliminary processing. Digital geophone and high-density acquisition method advocate single-point acquisition, and then use small distance and high coverage times to compensate the low signal-to-noise ratio of the data. Single-point receiving gets rid of the influence of geophone combination effect and observation mode, which is beneficial to improve the fidelity of data. So, can single-point reception replace detector combination now? First of all, the reception of seismic waves should include three aspects:

(1) Digital seismograph with small sampling rate, large dynamic and single channel and single station.

(2) Explosive source and non-explosive source.

(3) The geophones should be lowered into the well and received in combination.

(4) Excitation conditions and excitation modes of seismic waves. Single-point receiver mostly adopts digital detector, while analog detector refers to zero-base-distance receiver.

Compared with analog geophones, digital geophones have the advantages of large dynamic range, small distortion, wide frequency response, small equivalent input noise and strong maximum input signal, etc., which are beneficial to the reception of weak signals and high acquisition accuracy, especially suitable for high-resolution acquisition. Single point reception has many advantages for data quality. The biggest feature of geophone combination reception is to suppress random interference, and the prominent effective signal is received by single-point geophone, which can achieve high resolution. When combined detection is adopted, the detector acts as a filter, which will filter out high-frequency signals. Therefore, as effective means to improve the resolution, single-point reception and high-density acquisition have achieved good results in some areas, but in some areas with low signal-to-noise ratio, single-point reception is difficult to make a breakthrough in improving the signal-to-noise ratio of seismic data, let alone the resolution. Therefore, combined detection is the main measure to improve the signal-to-noise ratio of data. Therefore, the quality of the original data can be improved by adopting the receiving mode of geophone combination. Therefore, it is proposed to study the number of geophone combinations and the spacing of geophones from the perspective of the direction and frequency characteristics of geophone combinations. Transform to frequency domain and superimpose to obtain the total output of the detector, shown in formula(1):

$$\begin{aligned}\varphi(m) &= f(m) + f(m)_e^{-m\Delta} + f(m)_e^{-2m\Delta} + \ldots + f(m)_e^{-xm\Delta} \\ &= f(m)\{1 + 2[\cos mn\Delta t + \cos(n-1)m\Delta t + \cos(n-2)m\Delta t + \ldots]\}\end{aligned} \tag{1}$$

After combination, the frequency characteristic relationship is obtained, as shown in formula (2):

$$Q(m) = 1 + 2\begin{bmatrix}\cos mn\Delta t + cso(n-1)m\Delta t + \\ cso(n-2)m\Delta t + \ldots\end{bmatrix} \tag{2}$$

According to this formula, the frequency characteristic Figure 2 and Figure 3:

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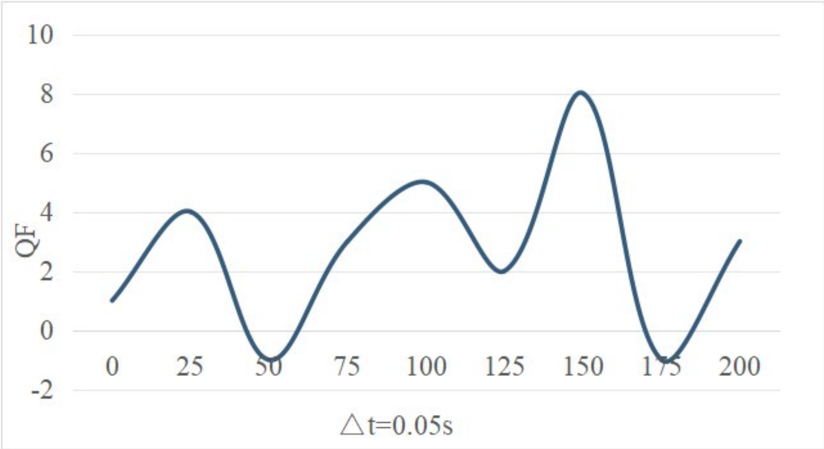

Figure 2: n = combined frequency characteristic curve of 5 detectors.

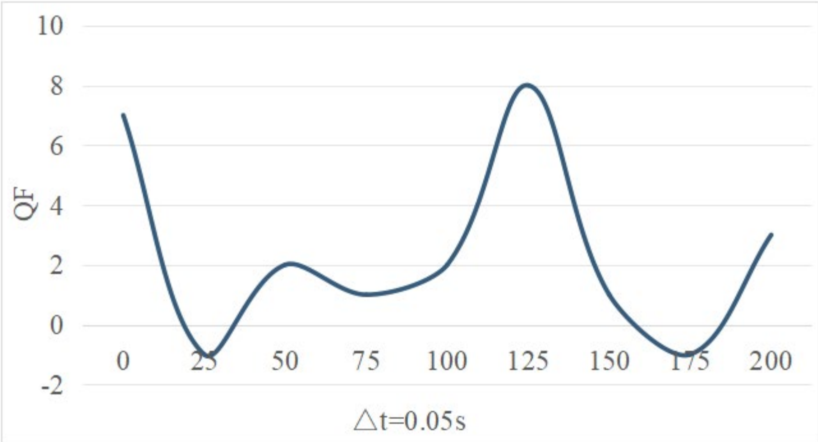

Figure 3: n = frequency characteristic curve of 7 detectors combination.

3.2. Principle of detection wave combination method

Assume that geophones S1 and S2 are placed on the ground, and the distance between them is set as Δg, the local seismic wave passing speed is x Media, $S1$ The seismic wave received by the point geophone is set as $F(s1) = Ao\cos 2\pi ft$. where is, $A0$ the amplitude; f Is the frequency; t For the propagation time.

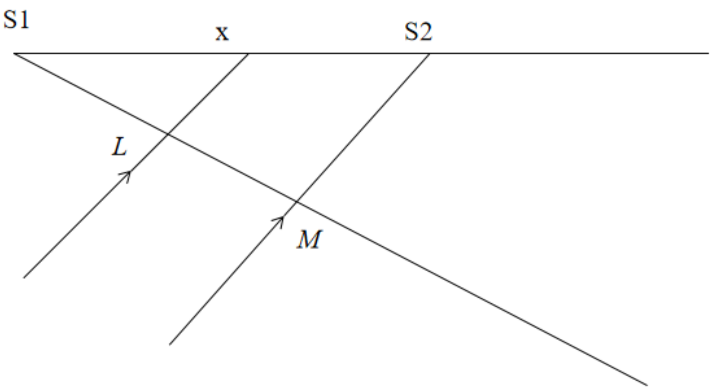

Figure 4: geophone combination model

The simplest linear combination has a frequency of f , Speed is v, Wavelength is λ Harmonic regular waves along the surfaceDirection spread,Ruozai x On the axis, two intervals are y detector reception, The combined detection result is obtained by adding the outputs of the two detectors.We call y is the combination distance, Is a selectable parameter in combined detection.If you choose $y=\lambda$ time, After the combination, the amplitude can be doubled, and the amplitude is zero due to positive and negative cancellation. It can be seen that the combined signal can be enhanced or weakened by selecting different combination distances for seismic waves with different wavelengths.According to the superposition principle, when we put n detectors are connected to output as one detector,Then its output Y , as shown in formula (3):

$$\varphi_N\left(\frac{\Delta y}{\lambda}\right)=\frac{\sin n\,\pi\dfrac{\Delta y}{y^*}}{\sin n\,\pi\dfrac{\Delta y}{\lambda^*}} \tag{3}$$

In order to realize single-point reception, the analog geophone combination adopts zero base distance or small base distance, and some combination point distances adopt $2m$,Some of them are stacked directly, with great randomness and lack of scientific basis. This problem is mainly discussed from the aspects of random interference suppression and geophone combination graphic design. First, random interference is time h And receiving point position two. $u(x,t)$. Fixed receiving point position $u(xR,t)$ It is a waveform record in the conventional sense; At a fixed moment, $u(x,Rt)$ It's a wave profile of random interference.

3.3. Equipment utilization and track spacing selection

Whether the power utilization rate of equipment is sufficient is an important index to measure whether the design of machinery and equipment is reasonable. At present, the power utilization rate of hydraulic system of domestic hydraulic feed core drill is very low, especially in the process of feeding, the power of hydraulic system is almost completely lost. Therefore, the track spacing should adopt the trail spacing.Whether the power utilization rate of equipment is sufficient is an important index to measure whether the design of machinery and equipment is reasonable. At present, the power utilization rate of hydraulic system of domestic hydraulic feed core drill is very low, especially in the process of feeding, the power of hydraulic system is almost completely lost. Therefore, the track spacing should adopt the trail spacing.

Trail distance itself is a kind of velocity filtering, which can improve the resolution. From the perspective of comparative interpretation of seismic waves, the distance is discussed. x Hours, record the time difference between adjacent tracks on the x Then the in-phase axis of small effective wave is prominent, and the contrast characteristics of small faults are obvious. The acquisition parameters are demonstrated by computer software, including bin size, coverage times, maximum offset, trace distance, combined base distance, vertical and horizontal resolution, etc. Or the feeding speed of pressurization and decompression is the same, which is 3.5m/h.. When feeding under reduced pressure, the oil pump only provides a certain force for the lower cylinder, so that it has a certain pressure. All the oil pumped by the oil pump and the oil discharged from the lower cylinder are discharged into the oil tank from the sulfur overflow valve.

Or the feeding speed of pressurization and decompression is the same, which is 3.5m/h.. When feeding under reduced pressure, the oil pump only provides a certain force for the lower cylinder, so that it has a certain pressure. All the oil pumped by the oil pump and the oil discharged from the lower cylinder are discharged into the oil tank from the sulfur overflow valve.

The oil discharge amount of the lower oil cylinder is shown in formulas (4) and(5).

$$Q_Z=Q_2+Q^2 \tag{4}$$

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$$Q_2 = V^2 F^2 \tag{5}$$

We should also pay attention to increasing the speed of reversing the rod, processing high-frequency data, reducing the time cost, and making the flow rate of the oil pump larger. There are also pipe wrenches working. Due to the large flow rate of pipe wrenches, the required flow rate of pipe wrenches should not be less than 35 liters/minute. As for chuck cylinder and moving cylinder, the ratio of time to flow is small, so it can be ignored. Generally speaking, the requirements of oil pump flow rate of each actuator in hydraulic system of hydraulic feed drilling rig are very different. In addition, it is necessary to strengthen the maintenance of floor concrete. Moisturizing and curing of concrete can avoid surface dehydration and greatly reduce the occurrence of initial expansion cracks of concrete. Although in actual construction, due to the tight construction period, the exposed concrete often lacks sufficient maintenance, so it is particularly important to make up for the cracks. It is not only caused by the negligence of concrete maintenance, but also the floor cracks caused by various reasons, so we should always pay attention to it.

4. Coal seam characteristics

Through many times of high-resolution 2D seismic exploration in coalfields, we have summarized high sampling rate, high bandwidth, high frequency geophones, small dosage, small offset distance and small borehole diameter. Because of the different conditions in coal fields, we must first design the well depth to avoid vulgar zone and quicksand layer. However, in actual work, there are often accidents such as penetrating quicksand layer, which leads to the explosive not reaching the specified depth and serious loss of high-frequency effective wave.

Therefore, we should try our best to increase the continuity of drilling work, and equip it with high-powered pumps, and we have described the dosage in detail above. Using compound dosage can better achieve the goal. The types of explosives need to be considered. At present, the commonly used explosives mainly include nitramine explosive and emulsion explosive TNT explosive. In order to achieve better results, emulsified high detonation velocity explosives are generally used, and suitable explosives should also be selected.

Secondly, frequency spectrum analysis and velocity analysis, especially in the area where the face changes suddenly, should be done more experiments. The filter test is based on spectrum analysis. Because the propagation speed and density of coal seam are lower than those of mudstone and sandstone, the wave impedance interface formed between the original coal seam and surrounding rock will no longer exist after the coal seam is lost in the deposition, so that the strong reflection formed between the original coal seam and surrounding rock will be replaced by messy or short continuous reflection, but the reflection characteristics of the underlying strata remain basically unchanged. The existence of various interference waves seriously reduces the signal-to-noise ratio and resolution of the superimposed section, thus affecting the discrimination of small faults and small geological bodies.

In areas with very complicated underground geological conditions, such as gravel beds or igneous rock distribution areas, due to their uneven distribution in the horizontal direction, the actual time is too small in areas with thick distribution, while it is too large in areas with thin or no distribution, which brings "traps" to interpretation.

5. Conclusion

Great progress has been made in field high-resolution seismic exploration and acquisition technology, which is the best way to solve the fine underground geological structure, while coalfield geological exploration is a fine and complex system engineering. In the process of geological exploration, every explorer must have professional knowledge and sense of responsibility, and reasonably adopt advanced geological exploration technology and exploration equipment, and make improvements from three aspects: instrument development, data processing means and field work methods. In order to get the ideal effect, and the data acquisition of high-resolution exploration should be from:

(1) Start with well depth, deviation, quantity and category of explosives.

(2) The exploration depth of coal field is relatively shallow. In order to obtain better reflection of coal seam, high resolution should be given priority to, supplemented by improving signal-to-noise ratio,

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and the combination method should be used to consider the demand.

(3) The combination of geophones should be based on the different demands of coalfields, and the data should be obtained by combining techniques.

The above three aspects are considered comprehensively.

Finally, it is worth pointing out that in the process of high-resolution seismic work, we must pay attention to the strong flattening effect of strata on high-frequency information, improve the signal-to-noise ratio and do well the static correction, etc., in order to get the ideal effect.

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