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Application of Seismic Channel Wave Technology on Small Structure Exploration in Coal Mine

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Abstract: At lane 20207 and lane 50207 of the 80207 working face of Sitai Mine, many small faults are exposed, and their extension is unknown, which causes great interference to safe and efficient mining and even normal production of the working face. In order to guide the rational transformation and safe and efficient production of the working face with science, Sitai Coal Mine commissioned Henan Polytechnic University to find out the extension of the exposed fault on the face and other geological anomalies by using geophysical exploration methods. According to the purpose of geophysical exploration in Sitai coal mine, combined with the geological conditions of the working face, the SUMMIT II EX type seismic channel wave exploration produced by DMT company of Germany is selected to explore the 80207 working face with the combined detection method of transmission and reflection. According to the detection results, combined with the existing hydrogeological data of Sitai mine, the relative channel wave anomaly area is delineated. The results show that the seismic channel wave exploration can provide a basis for the prevention and control of mine water disaster conveniently and effectively.

Keywords: Seismic Channel Wave Exploration; Channel Wave Anomaly Area; Transmission Channel Wave Exploration; Reflection Channel Wave Exploration.

1. Introduction

Mine water disaster is one of the five major disasters affecting the safety of coal mine. In the prevention and control of mine water disaster, the way of drilling combined with geophysical exploration is often used to advance water exploration and release. The geophysical exploration methods include Seismic channel wave exploration [1], resistivity method, transient electromagnetic method and audio frequency electric method perspective. The No.8 coal seam currently being mined by four mines is affected by the top and bottom aquifers during mining. In order to eliminate the threat of water damage and ensure the normal production of coal mine, according to the actual geological situation of Sitai mine, this paper chooses to use In-seam seismic survey to detect the water richness of 80207 working face of Sitai mine.

2. Principles of Seismic Channel Wave Exploration

Channel wave exploration is a kind of seismic wave, also known as coal seam wave or guided wave. Seismic channel wave exploration[2] is a new geophysical exploration method that uses the geological information carried by the channel wave that is excited, formed and propagated in coal seam to probe the thickness change of coal seam, the distribution of gangue layer, the fault, the collapse column and the old kiln in the measuring area.

2.1. Transmission Channel Wave Exploration

According to different exploration purposes and layout, channel wave exploration methods are divided into transmission channel wave exploration and reflection channel wave exploration [3].This time, the transmission method of channel wave exploration was adopted in 80207. Transmission channel wave exploration is to arrange the source and receiving unit in different laneways. Shot excitation is fired in one roadway, and transmitted channel waves passing through the test area are received in another roadway[4]. Multiple parameters such as channel velocity distribution and channel propagation quality in the area covered by seismic rays between the source and the receiving arrangement are calculated to determine the thickness change of coal seam in the test area, faults with a drop greater than 1/2 coal thickness, and the location and scale of various abnormal bodies such as collapse columns and old kilns. As shown in Fig 1.

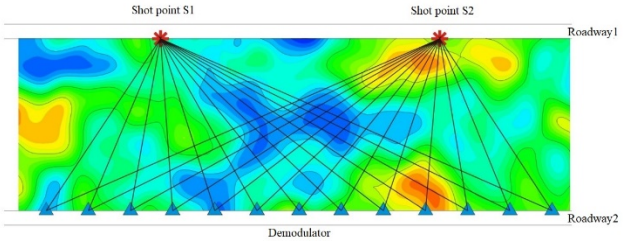


Fig 1. Schematic diagram of transmission channel wave exploration in the working face

2.2. Reflection Channel Wave Exploration

The reflection method of channel wave exploration is to arrange the source and the receiving unit in the same roadway respectively, and arrange the shot point and the detection point alternately to receive the seismic reflection signal[5] from the mining area or the working face. In theory, the detection distance of channel wave exploration by reflection method is 150 times the thickness of coal seam[6], which is mainly used to detect geological anomalies such as faults in coal seam that can form reflected waves, as shown in Fig 2.

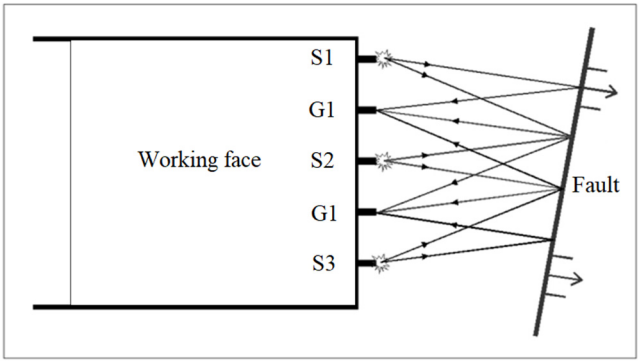


Fig 2. Schematic diagram of fault detection by reflection method

3. Design and Construction

3.1. Exploration and Design

The combined observation system of penetration and reflection method is used in the seismic channel wave exploration of 80207 working face, and the detector hole is constructed in the inner coal wall of 20207 lane. Construction of gun holes on the inner coal wall of lane 20207, cutting holes and lane 50207.The tunnel 50207 and the perforated explosive were detonated successively as the source to generate the channel wave, and the detector of tunnel 20207 received the channel wave data successively to carry out transmission exploration inside the working face. Then, the shot hole explosive in lane 20207 is detonated successively, and the channel wave data[7] is received by the original detector in lane 20207, and the reflected channel wave exploration is carried out on the working face.

(1) The excitation source used in the seismic channel wave exploration of the gun hole is the explosive type, the charge amount is 200g, and the detonation of a section of detonator is used. In lane 20207, 33 holes are designed with a distance of 30m.There are 54 holes designed for cutting holes and the inner side of lane 50207, and the hole spacing is 20m.The hole depth is 2m, the aperture is 42mm.The holes must be arranged in the coal wall, in a positive relationship with the roadway, and as far as possible in the middle of the coal seam.

(2) The hole acquisition instrument of the geophone is SUMMITIIEx explosion-proof channel wave seismometer. The geophone has two components of "X" and "Y", and the instantaneous dynamic range is ≥120dB, which can record channel wave signals with high fidelity. In lane 20207, there are 33 geophone holes with a distance of 30m, which are evenly arranged with the gun holes of the lane. The hole depth is 2m, the aperture is 55mm.The geophone hole must be arranged in the coal wall, in a positive relationship with the roadway, and located in the middle of the coal seam as far as possible., as shown in Fig 3.

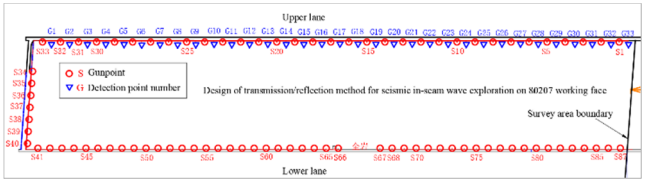


Fig 3. Design for channel wave exploration

3.2. Channel Wave Construction Situation

The Channel wave exploration project designed 87 shot points, 33 detection points, 75 actual construction shot points, 27 detection points. Among them, geophone holes G1, G7 and G33 are not constructed geophone holes, and G17, G25 and G31 are abandoned channels. The 12 guns, including S1-S6, S34, S35, S40, S58, S67, and S70, were either unused or failed to fire. Moreover, the blasting process failed to store solid blasting mud according to the design requirements, resulting in the leakage of blasting energy and secondary vibration interference, which adversely affected the quality of the original data collected and the data processing effect[8].

4. Data Processing and Interpretation

4.1. Transmission Channel Wave Exploration

The data processing of the transmission seismic channel wave exploration was carried out using the American SPW seismic data processing software[9], and the main data processing flow is shown in Fig 4.

The channel wave is a dispersive wave, that is, the group velocity and phase velocity of the channel wave change with frequency. The dispersion analysis is to extract the curve of group velocity and phase velocity with frequency from the measured channel wave records. Fig 5 shows the relationship between the frequency dispersion velocity value of channel wave and the thickness of coal seam in the case of a single coal seam[10]. The ordinate is the velocity and the abscess is the frequency. It can be seen from the figure that the change of slot wave velocity is closely related to the coal thickness. The thicker the coal seam, the lower the channel wave velocity and the more the main frequency shifts to the low frequency direction. In the part with the steepest change of channel wave dispersion, the change of channel wave velocity caused by the change of coal thickness is the largest, and the detection accuracy is the highest.

After the dispersion analysis of the channel wave data obtained at each shot point, the channel wave velocity at the selected frequency can be obtained[11], and then the wave velocity CT imaging results can be obtained by tomography. The results of CT imaging of channel wave velocity can reflect the thickness change of coal seam, fault and collapse column, etc., which is the main basis for geological interpretation of transmission channel wave exploration.

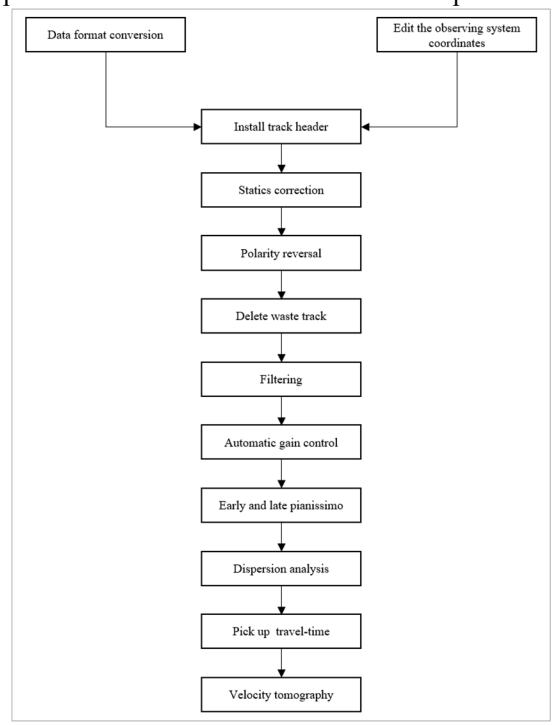


Fig 4. Transmission data processing flow chart

In this 80207 transmission channel wave exploration, the in-seam velocity of 125Hz was selected for CT tomography. The in-seam velocity of 125Hz has a good resolution for 5 ~ 7m coal seam, which is conducive to the in-seam detection of this working surface.

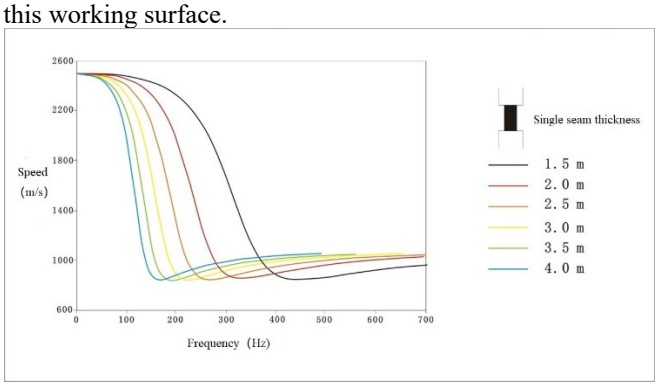


Fig 5. The relationship between the wave dispersion velocity of single seam and the thickness of seam

4.2. Reflection Channel Wave Exploration

The reflected channel wave exploration is in a coal roadway, where the channel wave data is received by one point excitation and multiple points at the same time. But the position of the small Angle oblique reflector can be given by the method of center point superposition Detect the fault, collapse column or goaf on one side of the roadway[12].

Compared with the seismic channel wave transmission method, the preprocessing and processing procedures are basically the same, with the addition of envelope superposition and the reduction of dispersion analysis and tomography[13].Its processing procedures are roughly divided into three steps: preprocessor, processor and common central point overlay (Fig 6).

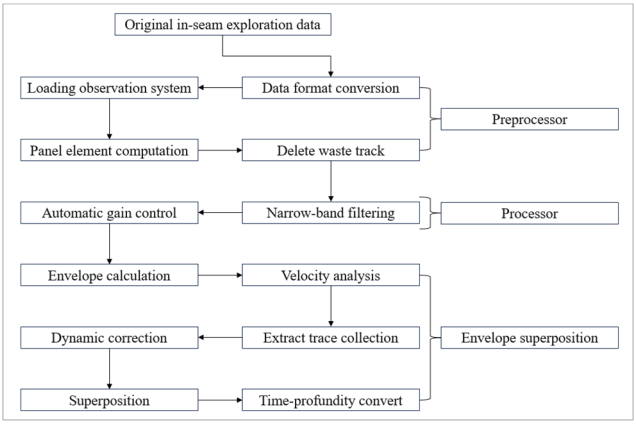


Fig 6. SPW reflected in-slot wave processing flow

5. Exploration Result

5.1. Transmission Channel Wave Exploration and Processing Results

There are 1728 seismic tracks designed by 80207 transmission channel wave exploration, 1296 seismic tracks in actual construction[14], and 528 effective seismic tracks picked up by identification and screening. The distribution of channel wave velocity and attenuation coefficient of channel wave energy in the measuring area are formed by CT tomography. The channel wave velocity distribution[15].

Diagram shows that the channel wave velocity is 700-1700m/s within the measurement area, and the channel wave velocity changes little at 85-480m and 760-880m away from the cutting hole, and there are 6 obvious channel wave high-speed regions in the other areas (Fig 7).

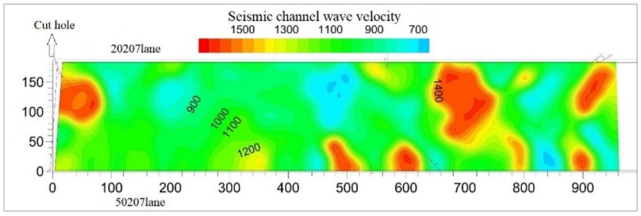


Fig 7. Velocity distribution diagram of 80207 channel wave

The distribution diagram of the attenuation coefficient of channel wave energy shows that the overall variation of the attenuation coefficient of channel wave energy within the measurement area is small, but there is a high attenuation coefficient in the position where the incisal fault develops (Fig 8).

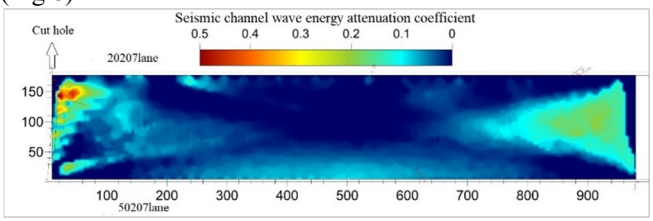


Fig 8. 80207 Seismic channel wave energy attenuation coefficient distribution

5.2. Reflection Channel Wave Exploration and Processing Results

There are 33 shot points and 33 detection points in the reflection channel wave exploration and design of lane 20207, and 27 shot points and 27 detection points in actual construction. The reflection overlay profile is formed by superposition of common center points (Fig 9).The superposition diagram shows that the reflected channel wave is not obvious in the whole range of the measurement area[16], and only a small amount of reflected trough wave exists in the area near the cutting eye and the 50207 roadway area.

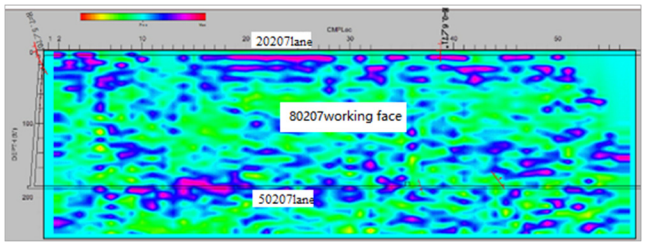


Fig 9. Lane 20207 reflected channel wave common center point superposition profile

5.3. Comprehensive Interpretation Results

After comprehensive analysis of transmission channel wave velocity distribution diagram, transmission channel wave energy attenuation coefficient distribution diagram and reflection overlay profile diagram of 80207 working surface, 6 major geological anomaly areas were found in the measuring area (Fig 10):

1# Abnormal area: 0 ~ 85m away from the cutting hole, near lane 20207.The anomaly area is predicted to be a fault extending to the interior of the working face with a length of about 90m, and is presumed to be the same fault as a normal fault with a drop of 7.5m revealed by the cutting hole. Anomaly area.

2# Abnormal area: located in the middle and upper part of

the working face 640 ~ 760m away from the cutting hole, it is presumed to be an internal hidden fault or other geological anomaly.

3# Abnormal area: 880 ~ 950 m away from the cutting hole, near Lane 20207. It is predicted that the anomaly area is two faults extending to the interior of the working face with a length of about 70m, which is consistent with the two faults revealed there.

4# Abnormal area: 480 ~ 545m away from the cutting hole, close to Lane 50207.It is predicted that there is a small fault or other geological anomaly in this anomaly area.

5# Abnormal area: 580 ~ 650m away from the cutting hole, close to Lane 50207.It is predicted that there is a small fault or other geological anomaly in this anomaly area.

6# Abnormal area: 530 ~ 580m away from the cutting hole, close to lane 20207.It is predicted that there is a small fault or other geological anomaly in this anomaly area.

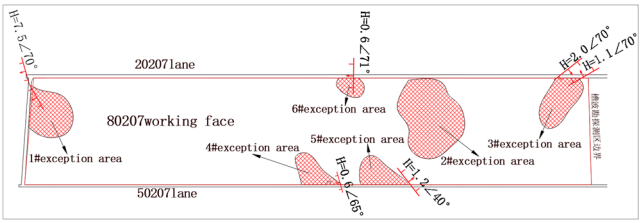


Fig 10. 80207 channel wave abnormal area exception differentiation layout

6. Drilling Engineering

6.1. Floor Anomaly Detection Project

Through geophysical exploration, it is found that there are 13 abnormal areas in the range of the working face, including 4 abnormal areas for pit penetration detection, 3 abnormal areas for audio electrical detection and 6 abnormal areas for channel wave detection. In view of the abnormal area, 26 boreholes were constructed and drilling verification was carried out, and 2 boreholes were flooded. The No. 2 anomaly area was not found in the process of excavation by trough wave detection, and it is speculated that it may be caused by hidden faults. Other anomalies are basically consistent with the revealed faults. As for the abnormal area of audio electrical detection, after drilling verification, there is water gushing in the detection holes at 760m and 280m in lane 20207.Through comprehensive analysis, the water gusher of borehole originates from K2 sandstone water and Cambrian limestone water.

6.2. Grouting and Effect Verification

Grouting was carried out on the two boreholes with verified water from the geophysical anomaly area, and the final pressure of grouting was 3MPa. The details are as follows: The geophysical anomaly verification hole at 760m of Lane 20207 was constructed perpendicular to the roadway, 0.2m away from the floor, with a dip Angle of -27°and a hole depth of 59m.On February 10, 2021, the drilled water was discharged with an initial water volume of 3.9m^3/h, and the water inflow was 1.3m^3/h on May 12. The grouting was completed on May 17, with a total grouting volume of 1.6t (water-cement ratio 1:1). After the grouting is finished, the inspection hole is constructed at 4.05m in the inner side of the borehole, perpendicular to the roadway, the position of the borehole is 0.2m away from the floor, the inclination Angle is -34°, the hole depth is 69m, and there is no water, indicating that the water plugging effect of grouting is good. The geophysical anomaly verification hole at 280m of lane 20207 is constructed perpendicular to the direction of the roadway, 0.1m away from the floor, with a dip Angle of -28° and a hole depth of 60m. The drilled water was discharged on February 12, 2021, with an initial water volume of 3.7m^3/h and an inflow of 0.5m^3/h on April 16. Grouting was completed on May 19. The total grouting volume is 1.3t (water-cement ratio 1:1). After the completion of the grouting, the inspection hole is constructed at 3.35m in the inner side of the borehole, perpendicular to the roadway, and the position of the borehole is 0.2m away from the floor, the inclination Angle is -36°, the hole depth is 68m, and there is no water, indicating that the grouting water plugging effect is good.

7. Mining Verification

The mining process of 80207 face shows that most of the geophysical anomalies are caused by small faults, which is consistent with the previous geophysical exploration results. The No. 2 anomaly area is interpreted as a hidden fault, which is verified by mining as being caused by three reverse faults with a drop of 1.5~4.5m, which is consistent with the previous detection results. The YC2 anomaly area explored by audio frequency electrical method can be interpreted as the rock layer in this area is relatively broken, fissure developed, and has a certain water-rich, which is consistent with the actual mining revelation that this is a small synclinal structure, the rock is crushed and easy to form a catchment area (Fig 11).

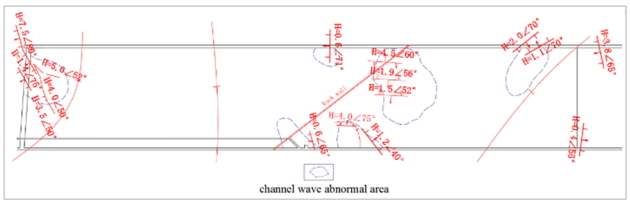


Fig 11. Face stoping exposure map

8. Conclusion

(1) Seismic channel wave exploration provides a convenient and effective technical means for the prevention and control of mine water disaster in underground coal mines. However, like other geophysical exploration techniques, Seismic channel wave exploration has its adaptability. In practical exploration applications, we should be good at exploring and summarizing.

(2) Due to the shooting process failed to store solid mud according to the design requirements, resulting in the leakage of shooting energy and secondary vibration interference. The quantity, quality and location of shot points and detection points in the actual construction of channel wave exploration do not strictly comply with the design requirements, and the effective data cannot uniformly cover the detection area, which affects the detection accuracy, and the mine water gushing is also related to many factors, such as recharge conditions, the development and connectivity of related water-bearing structures, water head pressure, coal seam thickness, mining method, and mining speed. With the constant change of the above factors, the mine water inflow, water inflow position and time will also change to a certain extent. Therefore, it is necessary to strengthen hydrological observation and data collection in the process of mining, and timely feedback should be given if anomalies are found, and corresponding water prevention and control measures should

be taken to control them.

(3) The channel wave exploration works carried out on the first mining face of No. 8 coal seam of Carboniferous series in Sitai Mine have detected 6 abnormal areas. After mining verification, the seismic channel wave exploration results are basically consistent with the actual geological conditions revealed during mining. In particular, the No. 2 anomaly area identified by channel wave exploration has been proved to be caused by three hidden faults with a drop of 1.5~4.5m along the working face, indicating that the geophysical interpretation results are in good agreement with the geological analysis results. The safe mining of 80207 working face is realized, which provides technical guidance for the mining of carboniferous coal seam under similar geological conditions in Datong mining area, and has strong practical significance.

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