ISSN: 2664-9640

Research on the Influence Range of Hydraulic Fracturing in Coal Mine Underground Based on Transient Electromagnetic Method

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Abstract

Hydraulic fracturing of underground drilling in coal mines is a technical measure for enhancing the permeability of underground coal seams. According to the characteristics of sensitive reflection when transient electromagnetic instrument detects to low resistance object, based on the intrinsically safe YCS360 transient electromagnetic instrument, the transient electromagnetic method is adopted to monitor the hydraulic fracturing effect of 7 hydraulic fracturing holes in N1640 South Gas Lane of Songzao Shihao M6-3 coal mine for test. It is found that the apparent resistivity of the fracturing bores corresponding coal seam position produces a distance variation ranging from 24.9m to 119.7m before and after fracturing, and there is a big difference in the range of influence of fracturing. Therefore, the transient electromagnetic exploration instrument can effectively detect hydraulic fracturing affect regional distribution, the result can optimize coal seam fracturing design and provide important reference basis to improve the fracturing effect of coal seam.

Keywords

Coal mine underground, Transient electromagnetic method, Scope of hydraulic fracture monitoring, Hydraulic fracturing.

1. Introduction

Hydraulic fracturing is an important measure for coal seam increasing permeability and has become an important means of coal mine gas drainage [1-2]. Permeability improvement in low permeability coal seams can obtain a good gas drainage effect. Hydraulic fracturing range monitoring is one of the key factors that restrict the application of hydraulic fracturing technology. Obtaining the data of coal seam hydraulic fracturing range is the basis for comprehensive evaluation of coal seam hydraulic fracturing effect, simulation prediction of coalbed methane development and analysis of direct effect of gas drainage. Coal seam fracturing is indeed different from fracturing in conventional formations in some respects [3-4]. Coal mine underground simulation results show, fracture affected area location distribution is more complicated than expected, there may be a composite area of influence between the horizontally affected area and the vertically affected area [5]. Therefore, it is urgent to conduct an in-depth study on the regional distribution of coal seam hydraulic fracturing.

In order to evaluate the range of hydraulic fracturing, a series of fracturing range monitoring techniques have been formed. At home and abroad, techniques such as underground microseismic monitoring, inclinometer monitoring, and distributed acoustic sensing (DAS) are widely used to understand and evaluate the characteristics of coal seam hydraulic fracturing range [6-7]. However, due to the presence of natural cracks and other heterogeneous

ISSN: 2664-9640

anisotropy in the coal seam, the stress wave propagation velocity and the energy frequency reduction amplitude have a great influence, and the monitored signal is weakened due to the influence, so it is not suitable for microseismic monitoring. The inclinometer has a lower resolution with increasing well spacing or depth and cannot be used in deep wells. Distributed acoustic sensing crack monitoring was first used in field fracturing monitoring in 2009 and is still in its infancy. Although the above monitoring methods have achieved certain results, they all have great limitations. In the long run, it is necessary to develop domestically produced technical equipment to reduce operating costs and achieve the purpose of promotion and application [8-11].

2. Transient electromagnetic detection basic principle and equipment

Transient Electromagnetic Method (TEM) is a pulse-induced electrical method that belongs to the time domain electromagnetic method [12]. The technology is to use a non-grounded return line or a grounding line source to send a pulsed electromagnetic field of certain waveform in an underground roadway. During a pause of a pulsed electromagnetic field, using a coil or a grounding electrode to observe a secondary eddy current magnetic field or the spatial and temporal distribution of electric fields induced by the pulsed electromagnetic field, to find aqueous geological anomaly. Transient electromagnetics are sensitive to low-resistance bodies, and are especially sensitive to low-resistance bodies such as water bodies and metal pipes in coal mines. Since the water is injected into the coal seam during the fracturing process, after the fracturing, the fracturing water should be stored in the coal seam cracks in a short period of time when the water discharge operation is not performed, at which time the coal seam has a lower electrical resistivity than the surrounding rock. Using the low-resistance characteristics of the water-bearing coal seam, the range of the water-bearing coal seam is detected by a shallow lead transient electromagnetic method.

This test uses YCS-360 mine multi-channel transient electromagnetic instrument, which is mainly collected by YCS-360Z mine intrinsically safe multi-channel transient electromagnetic instrument host and YCS-360C mine intrinsically safe multi-channel transient electromagnetic instrument collector, as shown in Fig.1.

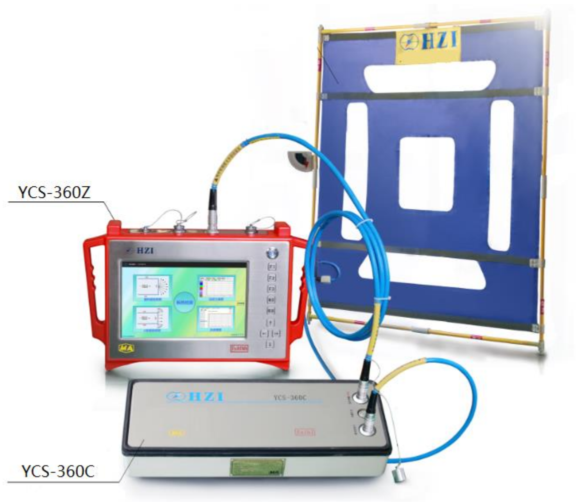

Fig.1 YCS360 mine multi-channel transient electromagnetic instrument system

3. The design and implementation of hydraulic fracturing boreholes

Field test on the application of transient electromagnetic method to test the effect of hydraulic fracturing in N1640 South Gas Lane of Songzao Shihao Mine, Test equipment using YCS360

ISSN: 2664-9640

transient electromagnetic instrument. The fracturing target coal seam is M_{6-3} coal seam (protective layer). A total of 7 fractured holes are arranged. The aperture is φ108mm, the distance is 100m, and the inclination is 70 degrees. The plan view and sectional view of the hydraulic fracturing drilling arrangement are shown in Fig.2.

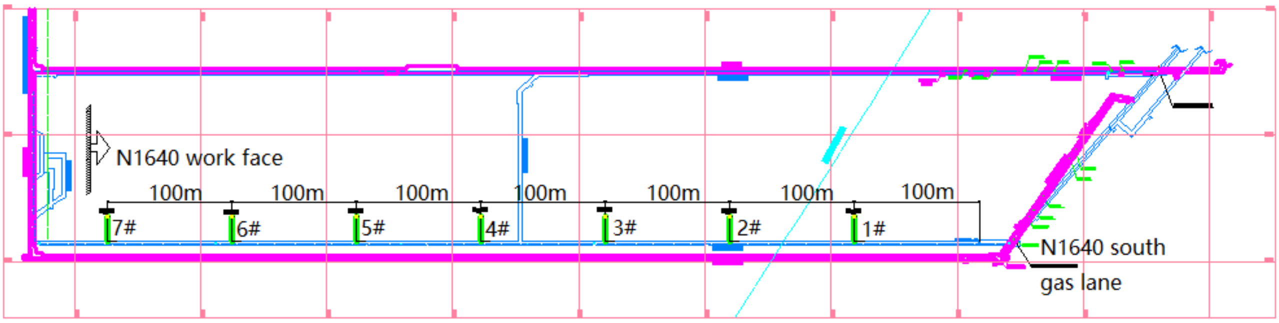

Fig.2 Schematic diagram of hydraulic fracturing drilling arrangement

4. Fracture monitoring program design and effect investigation

According to 10m spacing to scan coal seam in N1640 South Gas Lane. Scan 7 points per measuring point. The north side scans five angles, respectively 15 degrees, 30 degrees, 45 degrees, 60 degrees, 90 degrees; the south side scans two angles, respectively 45 degrees, 60 degrees. The scanning direction is shown in Fig.3.

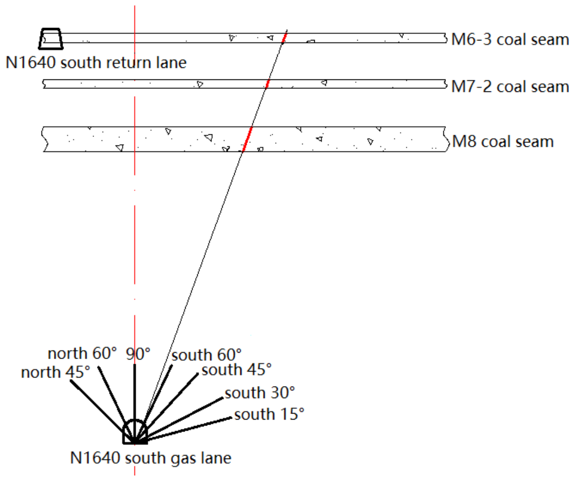

Fig.3 Schematic of the scanning direction of the transient electromagnetic instrument

In order to improve the detection effect, the contrast analysis method is used to analyze the area affected by the fracturing after water injection, that is, the detection is completed twice. Perform a probe before water injection, record the secondary field attenuation curve as the background field and convert it to apparent resistivity. After water injection, a probe was taken before the drainage was taken, and record the secondary field after the water injection and converted it to apparent resistivity. The coal fracture range is judged by eliminating the background field method and the comparison of the two detections before and after the water injection.

After the scanning is completed, the collected data is analyzed by software, and sliced separately at the position corresponding to M_{6-3}, and the apparent resistivity before and after fracturing of each slice position is as shown in Fig.4.

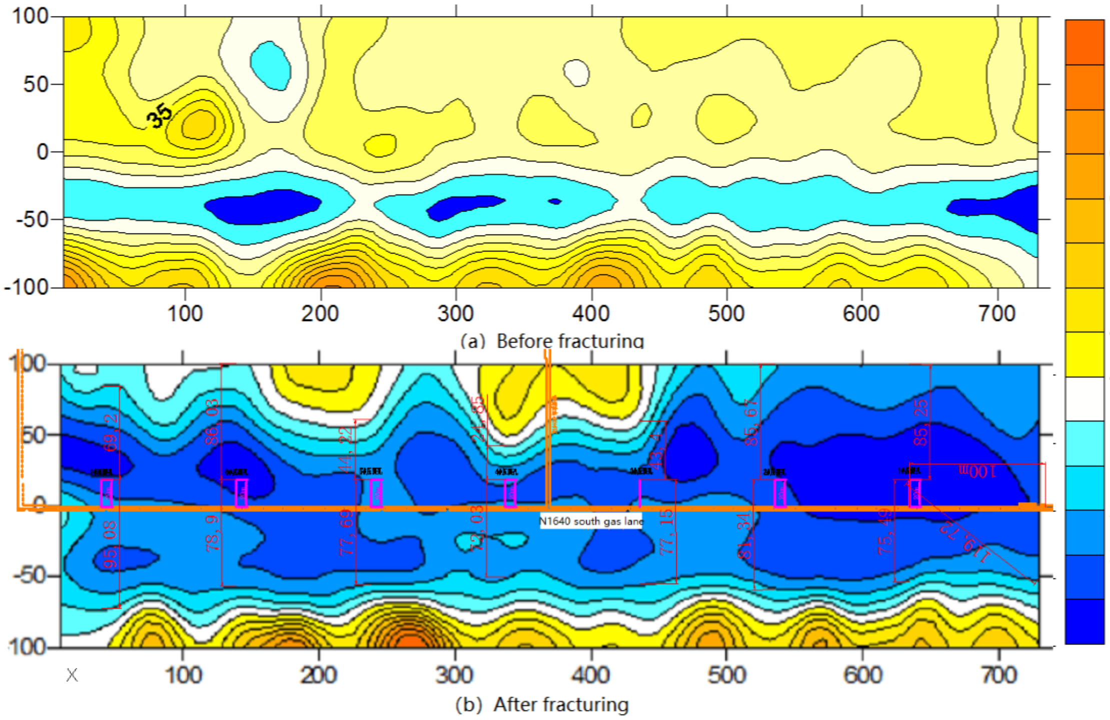

Fig.4 Comparison of the M6-3 coal seam before and after fracturing

As shown in Fig.4, the blue region represents the low resistance region and the yellow represents the high resistance region. Under normal conditions, the layer position is stable, there is no water-rich region and water-conducting structure, the electrical change is gentle, and the apparent resistivity value will not have obvious anomaly. It is reflected in the graph shows that the apparent resistivity value is small and contour distribution is even and gentle. On the other hand, if there is a water-rich zone (for example, water is filled after fracturing), the electric uniform distribution law is broken, and will appear anomalous areas with the apparent resistivity value decreases, the contour distortion, the deformation trap or the dense strip shape. The anomalous zone shows the diffusion range and connectivity of the low-resistance fracturing fluid, and presents an darker color on the color plan.

As can be seen from Fig.4(b):

(1) The apparent resistivity of each fractured borehole corresponding to the position of M_{6-3} coal seam before and after fracturing has changed, and the variation distance varies from 24.9m to 119.7m.

(2) The influence distance of 1# fracture hole in M_{6-3} coal seam is 85.25m or more in the north, 100m in the east, and 75.49m in the south.

(3) The amount of pressurized water of 1# fracturing borehole is 489m^3, so the distance affected by it is also the farthest, reaching 119.7m or more, indicating that the fracturing influence range increases with the increase of the amount of pressurized water.

(4) The 4# fractured borehole only expanded to the north side by 24.9m. Analyze the reasons was mainly caused by the influence of the borehole sealing and the geological occurrence of the area.

5. Conclusion

Through the transient electromagnetic method, the fracturing range of the hydraulic fracturing boreholes of the M_{6-3} coal seam in the N1640 South Gas Lane of Shihao Coal Mine was tested and the following conclusions were drawn:

(1) Transient electromagnetic method can detect the fracturing fluid penetration range of hydraulic fracturing. Before and after fracturing, the apparent resistivity of each fractured borehole corresponding to the $M_{6\text{-}3}$ coal seam position changes, and the variation distance is from 24.9m to 119.7m, the range of influence of fracturing increases with the increase of the amount of pressurized water, and is also susceptible to such factors as the borehole sealing and the geological occurrence of the area.

(2) Due to the unbalance of the stratum, the fracturing fluid mainly expands along the weak surface, and its extension range is not a regular geometric figure, and there is a big difference between the fracture influence ranges of each hole.

(3) Transient electromagnetic detection can utilize the low-resistance characteristics of water to detect the water-storing area of the fracturing coal seam, thereby indirectly inferring the fracturing range and the distribution of the hydraulic fracturing area. However, due to the thinner target coal seam, less fracturing water content, and more underground interference signals, the monitoring range has not yet reached the level of dynamic monitoring and complete quantification.

(4) Transient electromagnetic method requires high test conditions and is greatly affected by metal bodies. In the measurement, the interference of the metal body should be minimized, or the secondary field of the water-bearing coal seam should be extracted by removing the interference field.

Acknowledgments

The study was supported by Major Independent Special Funding Projects of Chongqing Research Institute of China Coal Technology and Engineering Group Crop. (202227003).

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