Coal mine water hazard accurate detection and efficient control technology based on comprehensive drilling methods

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Abstract

In order to prevent and relieve coal mine water hazards in China, mine water accurate detection and efficient control techniques were studied based on applications of multiple drilling methods. Surface directional drilling was applied in deep buried areas to cover main detection and governance region. Radial jet drilling technique was applied to control shallow area, marginal region and directional drilling blind area. In areas with no ground drilling condition, underground drilling technique was applied. Accurate detection method was developed by analyzing multi source data obtained through different drilling methods. Study showed that faults can be identified by directional drilling logging data and radial jetting process data. To enhance control efficiency, non-blind borehole layout method was studied by using different kind of drilling methods comprehensively.

Keywords: directional drilling, radial jet drilling, accurate detection, efficient control

Introduction

Water hazards in coal mines mean the phenomena that surface and underground water enters suddenly into a mine during construction and production. Water hazard in coal mines is related to factors such as geological tectonics, mining activities, geo-stress and hydraulic features of groundwater. As shallow coal resources in North China have become depleted, mining depth has gradually increased in recent years (Dong, 2007). Since Ordovician limestone comprise confined karst aquifers, and are characterized by extremely high water pressure, water leaking out of them is a huge threat. Deep mining flooding disasters in the past have led to considerable property losses and personal injuries. Water conducting channels such as faults are difficult to detect in advance using vertical boreholes despite the application of conventional fault detection methods. It is therefore of critical importance to detect water conducting channels for controlling groundwater hazard efficiently.

At present, water hazard prevention and control technology is developing towards regional, accurate and efficient control. Core part of mine water accurate and efficient control technologies is the integral drilling technology including surface directional drilling, surface radial jet drilling and underground long distance directional drilling. Comprehensive drilling technology extend data sources and can provide large amount multi source data which can be used as a basis for detecting faults and other structures. This paper is mainly about how to analyse different kind of drilling data and how to use multiple drilling technologies more efficiently.

Comprehensive drilling technologies

Surface directional drilling

Surface directional drilling is the major drilling approach for surface regional governance engineering, surface horizontal branch drilling means the drilling technology that a vertical borehole is drilled from the surface, turns into a horizontal well at definite angle in a target horizon. For surface horizontal directional drilling, multiple branch boreholes are drilled from a main surface borehole to control the range of grouting reconstruction in target aquifer, achieving the objective of regional grouting reconstruction, as shown in figure 1. After entering into the target layer, borehole extends horizontally or nearly

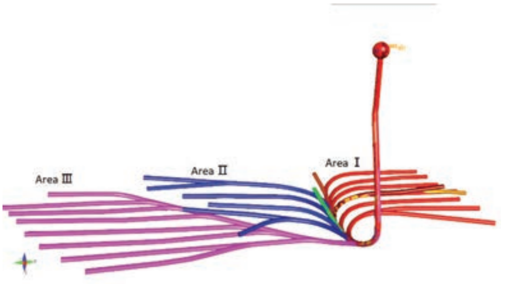

Fig.1 Subarea layout of directional boreholes

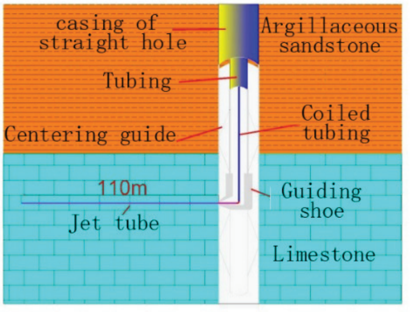

Fig.2 Schematic radial jet process

horizontally along the target layer, detects efficiently the development situation of karst, structure and fractures in the target layer within the scope of drilling, broadening the control range of the borehole, improving the groutability and the effect of reconstruction and reinforcement.

Surface radial jetting

Hole-forming technology with radial jet uses the principle of high pressure hydraulic cutting, relies on simultaneously forward and successively jetted high pressure water to form hole, as shown in figure 2. The jet of high pressure water cuts forward and break the surrounding rocks, provides backward power for the jet nozzle and the tube to move forward. The maximum jet pressure is up to 137MPa, the aperture of jet hole is 25~75mm, the maximum hole depth until now is 110m. In the same well multiple horizontal boreholes can be drilled in radial direction at the same stratum or different horizons.

Before drilling a radial borehole, a straight hole should be drilled firstly by using an ordinary rotary drilling rig, after the borehole enters into Ordovician limestone, the borehole is washed and drilling is ended to observe the static water level. Then pump in test is conducted to measure the specific water adsorption rate of the injected interval, suitable grouting materials and formula are selected to start grouting, after the technical grouting standards are achieved, the borehole is cleaned to start drilling of radial jet perforation. In principle, each radial perforation is completed in one time, later drilling and grouting are completed successively according to the sequence of perforation-forming by jet and grouting.

Underground directional drilling

The technology combining underground directional drilling and high pressure grouting can also be achieved, as shown in figure 3. An underground directional borehole consists of a casing interval, a rotary deflecting interval, a directional deflecting interval and a steady inclined interval (Li, 2013). A directional drilling technology with a positive displacement motor is used to conduct directional deflecting and steady inclined drilling, the borehole trajectory is measured in real time and controlled accurately so that the borehole extends at long distance in a targeted layer of grouting, when necessary, branch holes are drilled to increase the exposure range of an aquifer by borehole.

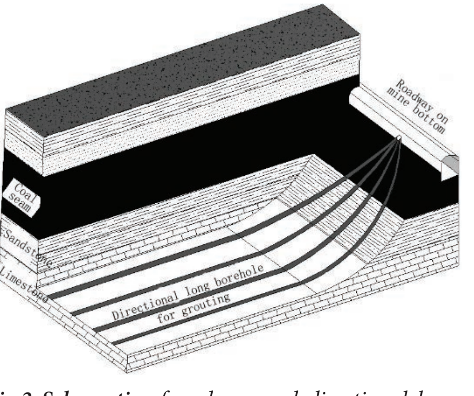

Fig.3 Schematic of underground directional boreholes

Accurate detection from multisource data

Fault identification based on directional borehole logs

The principle of natural gamma-ray logging while drilling (LWD) relies on the natural radioactivity of a formation and its standard unit of measurement is defined by the American Petroleum Institute (API). Natural gamma-ray parameters are used to precisely identify the characteristics of a formation in combination with geometric parameters of borehole trajectory and geological data. Thus, a higher logging value therefore implies a larger intensity of rock radioactivity (Fletcher, 2008). Figure 4 shows data series of natural gamma-ray LWD at four directional boreholes (S4, S5, S6, S7) of a regional control project at Xingdong coal mine in Hebei province.

In order to extract the implicit information of the fault in the natural gamma-ray LWD, we use the time-frequency analysis and Short Time Fourier transform. Time-frequency analysis can transform the GR data curve into time domain and frequency domain to explain, and it will highlight the change of the curve reflecting the fault information in these domains (Lu, 2013). Through this method, the results show that using Hamming window function and selecting 127 samples of window function we can calculate the amplitude and spectrum of the resistivity curves, which can greatly improve the ability of distinguishing fault zone.

Compared with the conventional method, the recognition rate of fault is increased by time-frequency analysis. When there is fault in the layer, the GR data will show an anomaly with respect to the bedrock. Thus, fault zones can be identified by the natural gamma-ray LWD in parallel directional holes. Combining geological data, all three high amplitudes can be inferred under the impact of the same fault, and are connected as line of fault trend on the flat surface, fault 1. The time- frequency analysis presented above shows that because the amplitude of the S5 hole is very high, between 2,673 m and 2,800 m, this is likely a fault point named Fault point. The distribution of faults on this plane is shown in figure 5.

Fault detection by jetting process data

It usually needs three boreholes to determine the occurrence and location of a fault. A fault can be exposed in a single vertical borehole by multiple jetting boreholes then the occurrence and location can be determined. Jetting hole should be constructed after drawing the projection profile in the area where the fault may exist. Jetting pressure should be selected according to different lithology. Fault point can be determined according to jetting phenomenon such as coiled tubing jump, tubing flabby, speed slow down or the change of proper jetting pressure. Three-point method can be used to determine fault occurrence and position based the determination of multi fault points, as shown in figure 6.

Borehole layout method for efficient controlling

Boreholes drilled by different kind of drilling methods provide grouting channels to control mine water. Usually a single drilling method is difficult to control the whole mining area comprehensively, thus, comprehensive drilling technologies should be combined under specific construction conditions. Borehole layout is constrained by various conditions

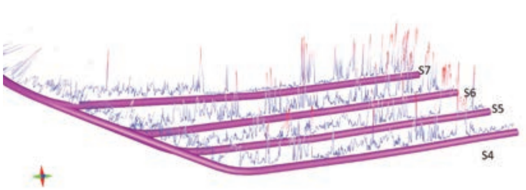

Fig.4 ***GR*** *data at four boreholes in 3D space*

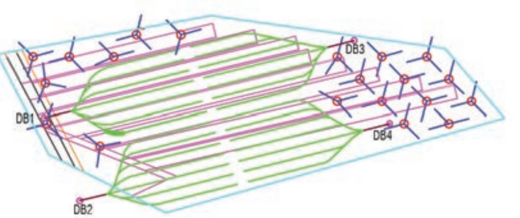

Fig.7 Borehole *layout for efficient controlling*

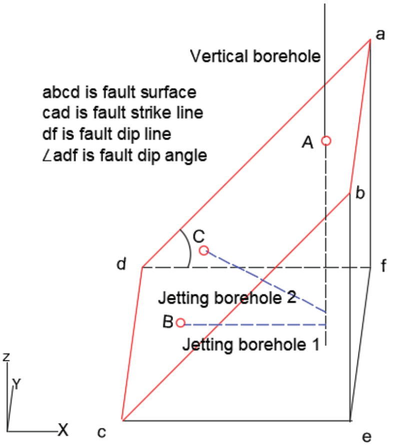

Fig.6 ***Fault*** *detection based on radial jetting*

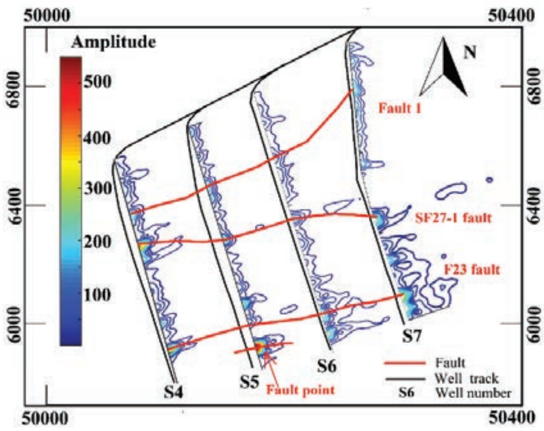

Fig 5 *Fault zones delineation based on four holes based on GR*

such as ground condition, mining plan and target layer characteristics. To enhance control efficiency, surface directional drilling and radial jet drilling methods were applied at a regional control area with water inrush coefficient larger than 0.1MPa/m of Dongpang coal mine at Hebei Province, as shown in figure 7. The regional control area is an irregular triangle and the grouting layer buried depth is from 420m to 640m. Surface directional drilling boreholes control the main scope while radial jet boreholes control shallow, edge and corner areas which is blind area of directional drilling.

Conclusions

Surface directional drilling technology is mature, has high drilling efficiency, less surface orifices, hole-forming by surface radial jet does not have requirement for the depth of straight hole, radial hole enters directly into formations , does not need a radius of turning circle, surface hole opening position does not have blind area, borehole layout is flexible. Underground radial drilling technology is not limited by ground conditions but by the distribution of workings.

Coordination of different drilling approaches can form control technology without blind area. Surface directional drilling engineering is arranged in areas of deeper burial depth. Shallow parts, corners and blind area of directional drilling are controlled by radial jet holes, the areas that surface drilling can’t cover are controlled by underground drilling so as to achieve the complete coverage of the whole controlled region.

In addition of normal detection methods, fault identification methods based on directional borehole logs and radial jetting process were put forward. Integral comprehensive drilling technology and accurate detection methods can achieve efficient control in areas with water hazards.

Acknowledgements

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