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Research on Complete Set of Gas Drainage Technology for Coal Mine Long Bedding Drilling

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Abstract*:* In order to achieve the purpose of coal mine long bedding drilling high-efficiency, the main factors affecting the hole-forming effect of the bedding drilling were analyzed, the technical ways to increase the hole-forming length of the soft outburst coal seam were studied, and a reasonable drilling construction parameters, wind slag discharge parameters and suitable auger rigs have proposed a new set of long bedding drilling gas drainage technology, and carried out on-site practice at the Wangpo coal mine 3212 working face. The results show that the drilling technology using spiral drilling and air pressure slag discharge, large-capacity spiral drilling rigs and supporting drilling tools are currently the main technical ways to increase the length of holes formed in soft and outburst coal seams. After using the new complete bedding gas drilling technology in the 3212 working face, the hole-forming rate can be increased from 7.5% to 14.3%, the average hole depth increased by 12.3%, and the average daily drilling footage increased by 26%. It shows that under the condition of extremely difficult coal seam drilling, the new set of gas drainage technology and equipment has stronger adaptability and better hole-forming effect.

Keywords Gas Drainage, Long Bedding Drilling, Complete Set Technology, Hole-forming Effect

INTRODUCTION

Wangpo Coal Mine has rich coal resources, with an area of 29.25km^2, geological reserves of 358.69Mt, and recoverable reserves of 200.25Mt. The mine development method is inclined vertical comprehensive development, and the coal mining method is fully mechanized top coal caving. The mine is a high-gas mine, and the main coal seam is 3# coal seam. The geological structure of the 3212 working face is complex, the coal seam is relatively broken, the ore pressure is relatively large, the burial depth is between 450m and 810m, the gas pressure is estimated to be about 0.9MPa, the gas content is about 16m^3/t, and the firmness coefficient(f) is 0.53.

At present, the 3212 working face uses the slag discharge technology of smooth drill pipe drilling, auger drilling, auxiliary air pressure, hydraulic power and the supporting ZYD-1900S drilling rig for the construction of extraction drilling. However, the hole-forming effect and the gas drainage effect of the mining face are not good. The existing technology and equipment for drilling along the coal seam can no longer meet the needs of mine drilling. Therefore, researching more advanced drilling construction technology, choosing more suitable construction equipment, and researching and exploring suitable construction technology parameters are the most direct ways to solve the existing problems.

ANALYSIS OF FACTORS AFFECTING THE EFFECT OF LONG BEDDING DRILLING

How to construct bedding holes in soft coal seam to ensure the depth and rate of borehole formation is the bottleneck factor that affects the success or failure of bedding gas extraction technology. However, under the specific conditions of coal seam in China, the technology of drilling along the bed in soft and outburst coal seam is the key factor affecting the depth and rate of hole formation [Lei, *et. al.*, 2009, Wang, 2010, Zhao, *et. al.*, 2013]. Therefore, it is a prerequisite for improving the depth and rate of hole formation in bedding drilling to study the bedding drilling construction technology suitable for the coal bed occurrence characteristics of Wangpo Mine and to select suitable equipment.

Selecting long boreholes for construction in high gas, high stress, soft coal seams, whether it is the traditional hydraulic slag discharge wet drilling method or the machine tool (spiral) slag discharge dry drilling method, there are many drilling resistance factors, mainly the following:

(1) High gas pressure. Due to the high gas content and high pressure of the coal seam, gas dynamic phenomena such as top drilling, spouting, and stuck drilling are likely to occur during the drilling process, and it will increase as the mine extends deeper.

(2) Coal seam is soft. Coal seam is relatively soft, especially in the geological structure zone, it is easy to

form pulverized coal, and it is extremely difficult to drill holes in this section.

(3) Large ground stress. Various collapse holes, deformations, and hole wall cracks caused by the influence of in-situ stress, tectonic stress and mining stress in coal seams are easy to cause stuck pipe.

Among the above-mentioned drilling resistance factors, either a certain leading role or multiple comprehensive functions will cause poor slag discharge during drilling, which seriously restricts the drilling speed and the depth of hole formation.

RESEARCH ON THE TECHNICAL WAYS TO INCREASE THE LENGTH OF HOLES FORMED IN SOFT OUTBURST COAL SEAM

Through investigation and analysis, it was found that the construction effect of bedding drilling in Wangpo Coal Mine was not satisfactory. It was mainly manifested in the serious collapse of the coal seam boreholes. The measures taken to ensure effective slag discharge are far from enough. Most drill holes fail to reach the expected depth due to blockage of drill cuttings and the occurrence of stuck pipes (or drills). Secondly, the existing drilling equipment such as drilling rigs and drilling tools cannot meet the construction requirements of long drilling along the layer. Therefore, the construction of long drilling along the layer should start with the study of effective slag removal technology and appropriate technical parameters, and at the same time select the large-capacity drilling equipment suitable for the construction conditions of the layer along the layer.

The Drilling Construction Technology with Using Spiral Drilling and Air Pressure Slag Discharge

(1) Spiral drilling technology

Spiral drilling technology is based on the mechanism that the drill bit cuts the coal body and moves forward, and the spiral blade continuously evacuates the chip. The hole forming method does not require flushing fluid, reduces the scouring of the hole wall, and effectively maintains the stability of the drilling hole, and the construction site is relatively clean [Peng, 1998, Wang, et. al., 2007 and Yao, et. al., 2017]. During the construction, the rotary hydraulic motor of the drilling rig drives the main shaft to rotate through hydraulic transmission. The front end of the main shaft is connected to the spiral drill rod with non-slip bolts. The coal dust spiral conveyor belt is formed between the holes, and the spiral blade continuously discharges the coal dust in the holes out of the holes. With this drilling technology, the gas rich in the holes can be gradually released, which can effectively prevent spraying hole to ensure the rate of pore formation.

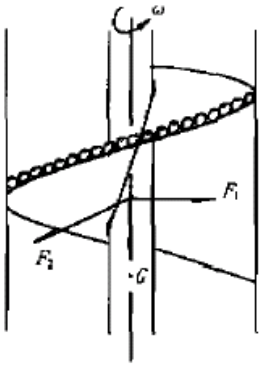


Figure 1. Movement mode of coal dust in borehole

(2) Pressure slag discharge method

The traditional slag discharge process is to use water as a flushing medium to carry and discharge drill cuttings and cool the drill bit. The advantage is that there is no dust in the operation site, which is in accordance with the drilling personnel's operating habits. However, the biggest disadvantage of this hydraulic slag discharge method is that the impact on the hole wall is too large, and the hole collapse and spray hole are serious. Compressed air slag discharge is a better slag discharge method for drilling in outburst or soft coal seams. It uses compressed air to pass through the inner hole of the drill rod and the drill bit to enter the bottom of the hole, forming a high-speed wind flow in the hole, and the drill cuttings are suspended in the wind flow and blown to the orifice, thereby achieving slag discharge and bit cooling. In the 1980s, China began to drill along the layer, but the depth of the hole formation is very small, and the deeper one is only about 70m [Bai, 2018, Xie, et. al., 2013, Li, et. al., 2011 and Yang, et. al., 2013]. The disadvantage of compressed air slag discharge is that the dust at the working site is not easy to control. The pressure and flow of compressed air provided by most mines are small, which cannot meet the requirements of long drilling. But its advantages are obvious. For example, the impact of compressed air on the hole wall is small, it is not easy to damage the hole wall, nor does it affect the coal gas desorption and discharge, so that the gas can be discharged freely and quickly, and the discharged gas and compressed air is mixed, there is always only two phases of gas and solid flow in the hole, and the possibility of obstruction is also reduced.

Therefore, in view of the characteristics of compressed air slag discharge and the actual conditions of drilling in outburst coal seams, the construction test of long boreholes along the layer of soft coal seam is mainly carried out by auger pressure slag discharge.

Adopt Large-capacity Spiral Drilling Rig and Supporting Drilling Tools

(1) Use auger rig with greater drilling capacity and high speed

As the length of the drill hole increases, the area of contact friction between the drill pipe and the drill hole and the weight of the drill pipe itself increase accordingly. Therefore, the rotation torque and propulsion force of the rig must be greatly increased. At the same time, considering that the bedding drilling is generally performed in the mining roadway with a small cross section, the cross section is small, and it also requires small dimensions and easy handling, which cannot be satisfied by the existing large-capacity drilling rigs.

In view of this situation, starting from a higher drilling capacity and requirements for drilling along a soft coal seam, it is necessary to select a new applicable auger drill.

(2) Drilling tools that use auger drilling and compressed air assisted slag discharge

Drilling tools mainly include drill bits and auger rods. By analyzing the influence of the structure type and parameters of the drill bit on coal slag production and slag discharge of different hardness, the drill bit that can reduce the slag size of the drill slag, facilitate slag discharge and has reasonable structural parameters is selected. Select a spiral drill pipe that can be used in the construction of long drilling along the layer of the 3# coal seam in Wangpo Mine. The drill pipe adopts reasonable materials, diameters, structure and speed parameters, as well as square buckle joints that can be reversed. It is helpful to improve the drilling depth and the effect of forming holes.

HOLE FORMING PROCESS TECHNOLOGY AND EQUIPMENT OPTIMIZATION

Through the above analysis, it is found that the determination of reasonable drilling construction parameters and wind slag discharge parameters, and the selection of appropriate auger drilling rigs can effectively improve the construction effect.

Main Parameters of Spiral Drilling

(1) Depth of hole formation: The drilling depth of the extraction hole should be determined according to the actual needs of the extraction work of the mine. The inclined length of the working face of the mine is 180m, then the drilling depth is generally required to reach 100~160m, and the ideal drilling depth is 160m.

(2) Diameter of hole formation: During the drilling and extraction process along the coal seam, the hole with a larger diameter is better than the hole with a smaller diameter. According to the actual extraction data of the mine, the diameter of the hole is greater than 85mm. It is more conducive to improving the drainage effect.

(3) Drilling speed: From the perspective of improving the rate of hole formation and construction efficiency, the ideal drilling speed is 0.5~1m/min under the conditions of coal seam.

Main Parameters of Wind Slag Discharge

The basic condition of wind slag discharge is that the wind speed in the borehole should be able to blow the large pieces of coal in the borehole, and the ability to blow out drill cuttings is greater than the amount of drill cuttings produced during drilling. To this end, according to the size of drill cuttings, drilling speed, etc., the pneumatic conveying theory is used to calculate the reasonable wind speed of the coal seam wind slag discharge to ensure sufficient slag discharge capacity. In order to ensure sufficient wind speed, sufficient wind pressure and volume are required.

(1) Wind pressure: According to the conditions of construction diameter of 110mm and depth of 100m, taking into account the retention of a certain wealth factor in the actual construction process, the wind pressure should be at least 0.5MPa. In the case of insufficient wind pressure in the underground pipeline, consider using a mobile compressor to provide greater wind pressure.

(2) Air volume: According to the conditions of the mine and the slag discharge condition of drilling on site, wind slag discharge is used to form holes, and combined with the actual situation on site, the minimum air volume required to ensure its normal slag discharge is 4.5m3/min.

Optimization of Drilling Tools

According to the specific conditions of Wangpo coal mine mining, in order to facilitate the construction of gas drainage holes along the coal seam and achieve the best gas drainage effect, the coal seam drilling capacity of the rig should be 150m~200m, and the final hole diameter is generally greater than 85mm. In order to be able to drill in coal seams with high gas complexity and geological conditions, the rig must have sufficient power to deal with possible accidents such as collapse holes and boring drills. At the same time, due to the small cross-sectional area of the roadway and fast cycle operation, the rig is required to be small in size, light in weight, and easy and fast to move.

Among them, the parameters of the auger drilling rig not only affect the structure of the drilling rig itself, but also relate to the efficiency of the drilling rig, hole-forming time, power consumption and improvement of working conditions. On the basis of fully considering the mutual influence between various parameters, the drilling tools suitable for the supporting drilling holes of Wangpo mine should have at least the following parameters:

(a) Hole diameter D: 90mm, 100mm.

(b) Drilling depth L: 150 ~ 200m.

(c) Drilling speed V: 0.5 ~ 1m/min.

(d) Drilling speed ω: 150 ~ 480r/min.

(e) The rising angle of spiral blade α: 21 ~ 31 °.

(f) The main motor power of the drilling rig N :> 55 kw.

Through the comparative test of the two types of drilling rigs and supporting drilling tools of ZYD-1900S (now using drilling rigs) and ZYW-1900R (new drilling rigs), as shown in Table 1. It is found that ZYW-1900R drilling rigs have larger power and supporting φ95mm spiral drill rod parameter design

More reasonable and other advantages. Therefore, the ZYW-1900R drilling rig was selected as the drilling tool for bedding drilling in this mine.

Table 1. Comparison of the parameters of two types of auger rigs

Model	ZYD-1900S	ZYW-1900R
Power / kw	37	55
Max torque / N.m	1900	1900
Connector	U-shaped card	nti-slip bolt
Drill rod length / mm	1500/1000	1000
Outer diameter /mm	100	95

FIELD APPLICATION

Based on the above determined construction process parameters, the ZYW-1900R drilling rig was transported to the 3212 transportation flume for the bedding extraction drilling construction. A total of 301 bedding extraction boreholes were constructed, with a total drilling length of 20108m and the average hole depth is 66.8m, the maximum hole-forming depth is 144m, and the average daily footage is 154.8m. At the same time, the statistics of the construction of the two auger rigs are shown in Table 2, Figure 2, and Figure 3.

Table 2. Comparison of the construction of the two auger rigs

Model	ZYD-1900S	ZYW-1900R
Number of holes	186	301
Total footage /m	11061.5	20108
Average hole depth /m	59.5	66.8
Max depth /m	123	144
Drilling success rate above 100 meters /%	7.5	14.3
Average footage m/d	122.9	154.8

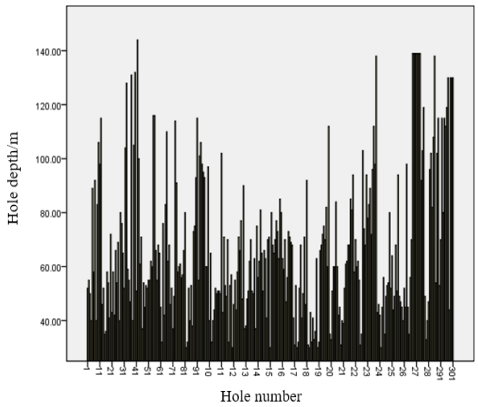
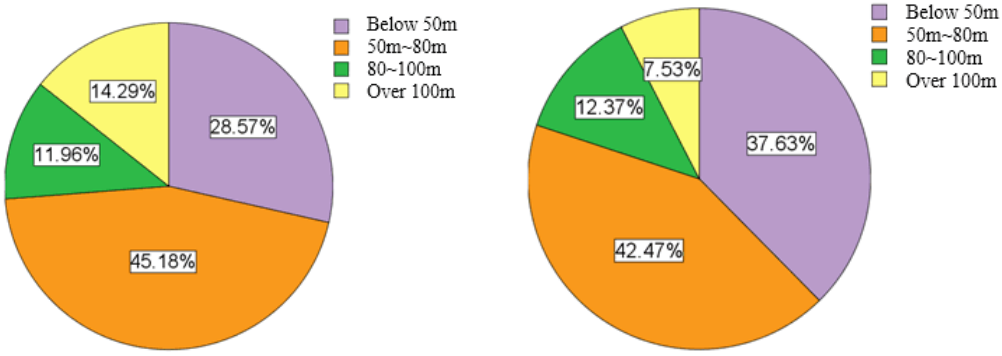


Figure 2. The layout of the new drilling rig construction drilling completion



a. Construction scale of new equipment *b. Construction scale of original equipment*

Figure 3. Comparison of construction depth between new construction equipment and original construction equipment

From the Table 2, Figure 2, and Figure 3, using the original equipment and process, the average construction depth is 59.5m, and the success rate of drilling holes above 100 meters is only 7.5%. The use of improved layered drilling technology and optimized construction equipment greatly improves the hole-forming effect and improves the work efficiency. The hole-forming rate of drilling holes over 100 meters reaches 14.3%, and the average hole depth increases by 12.3%. The hole construction footage is 154.8m/d, which is 26% higher than the original. It shows that under the condition of extremely difficult coal seam drilling, the improved construction technology and equipment have stronger adaptability and better hole-forming effect.

CONCLUSION

(1) The drilling technology using auger drilling, air pressure and slag discharge, and large-capacity auger rigs and supporting drilling tools are currently the main technical ways to increase the length of holes formed in soft outburst coal seams.

(2) By determining reasonable drilling construction parameters (hole diameter, hole depth, drilling speed, etc.) and wind slag discharge parameters (wind

pressure and air volume) and selecting a new ZYW-1900R auger, and a new set of complete drilling technology for gas drilling along the stratum has been formed.

(3) Through the on-site practice of 3212 working face, it is found that the new technology and method of long drilling along the layer can increase the hole-forming rate of the borehole over 100 meters from 7.5% to 14.3%, and the average hole depth is increased by 12.3%, the average daily drilling construction footage has increased by 26%, and a good on-site construction effect has been achieved.

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