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Analysis of Key Factors Affecting Deep Hole Drilling in Soft Outburst Coal Seams

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ABSTRACT

Due to the coal softness and poor gas permeability of outburst coal seam, it is very easy to cause spray holes, stuck drills, hole collapse and coal cannons during drilling. Based on the long-term on-site coal seam drilling experience, combined with theoretical analysis, the key factors that restrict the deep hole drilling of prominent coal seams are discussed in depth. The situation inside the hole after serious hole injection and its impact on deep hole drilling, the effect of entrapment in coal seams on deep hole drilling, the impact of top and bottom plates on deep hole drilling and the effect of coal cannons on deep hole drilling are analyzed. The in-depth analysis of the key factors affecting deep hole drilling can provide the important technical guidance for the efficient drilling of deep holes in soft outburst coal seams.

Keywords: *Soft outburst coal seam, gas drainage, deep hole drilling, key factors, analysis.*

1. INTRODUCTION

The key to highlighting gas management in coal seams is to adopt gas drainage, which is implemented by drilling [1]. The depth of the borehole determines the efficiency and effectiveness of gas management, but because the depth of the borehole in the outburst coal seam is limited by the existing technology, it is difficult to implement large-area and high-efficiency gas drainage in the outburst mine, giving it safety and cost with many negative effects [2]. For example, the excavation speed of the outburst coal seam is slow, which is only 1/5 to 1/10 of the speed of the non-outburst seam, which seriously affects the mining succession of the outburst mine. It is difficult to eliminate the "drainage blind zone" in coal mining face. When the blind mining zone is ignored, it is easy to induce outburst in the mining process [3]. Therefore, the sufficient attention must be paid to the design and implementation of boreholes during gas drainage in soft outburst coal seams.

However, due to the softness and poor gas permeability of the coal seam, the problems such as spray holes, stuck drills, hole collapse and coal cannons are easy to occur during the drilling process. At the same time, scholars at home and abroad have not made an in-depth analysis of the reasons for the difficulty in drilling soft coal seams. After the occurrence of spray holes, stuck holes, collapsed holes and coal cannons in the boreholes, the specific conditions in the boreholes have not been judged in detail [4-7]. Therefore, based on long-term on-site coal seam drilling experience and theoretical analysis, the author makes an in-depth discussion on the key factors influencing the deep hole drilling of soft outburst coal seams.

2. IN-HOLE CONDITION AFTER SEVERE BLOWOUT AND ITS EFFECT ON DEEP HOLE DRILLING

The section headings are in boldface capital and lowercase letters. Second level headings are typed as part of the succeeding paragraph (like the subsection heading of this paragraph). In the coal seam drilling test, there is an individual abnormal hole spraying phenomenon, that is, within a certain drilling length, nearly one ton or even a few tons of coal slag is sprayed out per meter of drilling, accompanied by a large amount of gas emission. Theoretically, with a Φ89mm drill bit and a drilling diameter of 100mm, the slag output per meter of drilling is about 11 kg. But the actual slag output is much larger than the theoretical slag output by about 100 times. Therefore, it can be seen that in the case of severe spraying, the drilling of the spraying section is no longer drilling, but should be a "drilling hole", otherwise it is difficult to explain the source of a large amount of cinder. So what form is in the "drilling hole"? First of all, the "drilling hole" cannot be empty. If the "drilling hole" is empty, the air velocity in the "drilling hole" will be very low, and the airflow will not have the ability to carry drilling slag. Secondly, it is impossible for the "drilling hole" to be completely filled with coal slag, otherwise the drilling will stop the slag discharge and even the air exhaust. Therefore, the "drilling hole" should be as shown in Figure 1.

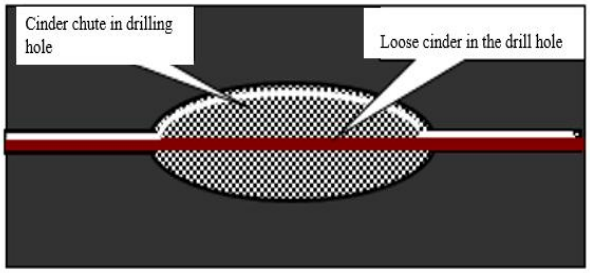

Figure 1 Schematic diagram of drilling holes in the hole after severe hole spraying

The slag chute in the "drilling hole" is at the upper part of the drilling hole. The drilling hole is basically filled with loose cinder, and the drill pipe in the "drilling hole" is always surrounded by the cinder. The influence of "drilling hole" on deep hole drilling is manifested in the following aspects.

(1) Drill pipe heating. The polished drill pipe continuously generates friction heat with the coal slag around it in the "drilling hole". The coal slag does not move and the heat cannot be taken away in time, which causes severe heat generation in the drill pipe. After the drill pipe heats up, the strength of the drill pipe will decrease sharply. Therefore, the "drilling hole" easily causes the drill pipe to heat up and break.

(2) "Drilling holes" can easily lead to blockage of drilling holes. The spray holes have caused excessive cinders. Part of the excess cinder is discharged out of the borehole, and the other part is stored in the "drilling hole" in a loose state. When the degree of looseness is not high, a cinder chute will be formed in the upper part of the "drilling hole". The slag chute is curved and has great resistance to air flow. Further drilling, once the deeper excess slag is encountered again, the slag chute in the upper part of the "drilling hole" is easily blocked, which is commonly referred to as drilling blockage. Here we call it "drilling hole" blocking. After the “drilling hole” is blocked, neither wind nor slag will be generated. This situation will occur for loose coal seams without particles. In this case, similar situations will often occur repeatedly by drilling back, and workers often have to stop drilling.

The foreign kilometer rig uses hydraulic slag discharge, and the domestic rotary rig has also tested hydraulic slag discharge, and has conducted drilling tests in soft and outburst coal seams in China. The reason for the unsuccess is that the "drilling hole" in the hole is constantly expanding and worsening. In the case of hydraulic slag discharge, the already soft coal body will become softer, and the "drill hole" will continue to expand, not only blocking the slag discharge channel, but also the drill bit or bottom hole motor will be hindered by the "drill hole" coal slag.

3. EFFECT OF ENTRAPMENT IN COAL SEAM ON DEEP HOLE DRILLING

Coal seam is a kind of non-linear heterogeneous material. There are bedding and intercalation in coal seam. Drilling through multiple beddings in the same direction multiple times will cause a gradual change in the drilling direction, which will have a certain impact on drilling, but the impact will be small. When the drill pipe encounters the pinch, it is divided into different situations according to the angle between the drill rod and the pinch layer, as shown in Figure 2. When the drill pipe is vertical or close to the level of the vertical pinch, the drill bit can generally pass through the pinch. After passing through the pinch, it can drill further into the depth, as shown in the middle case of Figure 2. When the angle between the drill rod and the pinch is very small and the pinch is relatively hard, the drill cannot enter the pinch and change direction along the pinch surface, as shown in the left side of Figure 2. When the angle between the drill pipe and the vermiculite surface is large, the drill pipe can pass through the clamp bar, and the drill pipe changes direction within the clamp bar.

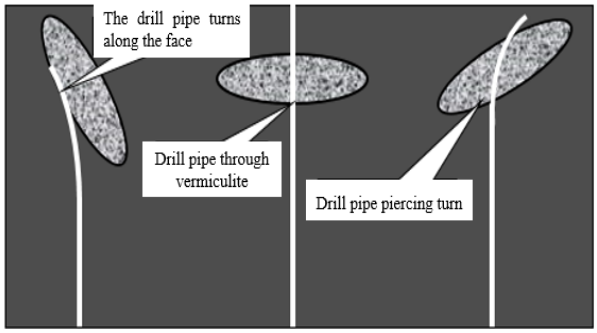

Figure 2 Schematic diagram of the impact of entrainment on deep-hole drilling

It can be seen from Figure 2 that the intercalation in the coal seam has a great influence on the deep hole penetration of the outburst coal seam. The intercalation will change the direction of the borehole and subject the drill pipe to bending stress. The middle case in Figure 2 is rare. The pinch in the coal seam will increase the rotation torque of the drill pipe and put the drill pipe in danger of being broken. There are three manifestations when the drill encounters the pinch: (1) the sound of the drill pipe has a knocking sound, (2) the front clamp of the rig appears to be different degrees of beating, (3) the propulsion resistance of the rig increases, and it retracts The resistance dropped sharply afterwards.

4. IMPACT OF TOP AND BOTTOM PLATES ON DEEP HOLE DRILLING

Drilling and encountering the top and bottom floors is one of the important reasons affecting the deep hole drilling of soft outburst coal seams. The reasons for drilling the top and bottom floors: the drilling direction is adjusted incorrectly, the pinch in the coal seam changes the drilling direction, the severe spray holes in the coal seam changes the drilling direction, and the power of the coal gun changes the direction of the drill pipe, and the sinking of the rig changes the direction of drilling.

Adjusting the direction of the rig is very important for deep hole rigs. Assume that the opening height from the coal seam roof is H meters, and the angle between the drill pipe and the roof is α, as shown in Figure 3. Assuming that the borehole does not undergo any bending, the formula for calculating the drilling depth when encountering coal seams is as follows:

$$L = \frac{H}{\sin\alpha} \tag{1}$$

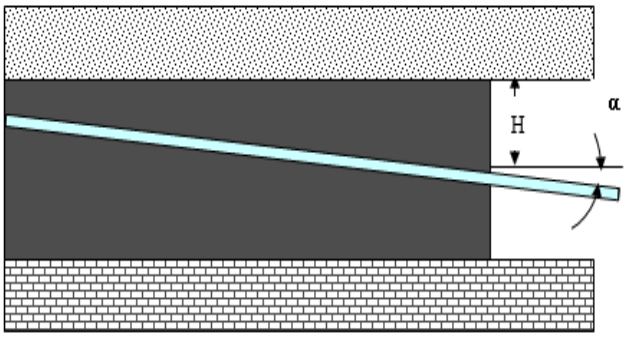

Figure 3 Schematic calculation of peaking depth and opening direction

Assume that the height of the hole from the roof or floor of the coal seam is 1.5m, take different angles, and calculate the drilling depth when the roof or floor is encountered according to formula (1), as shown in Figure 4.

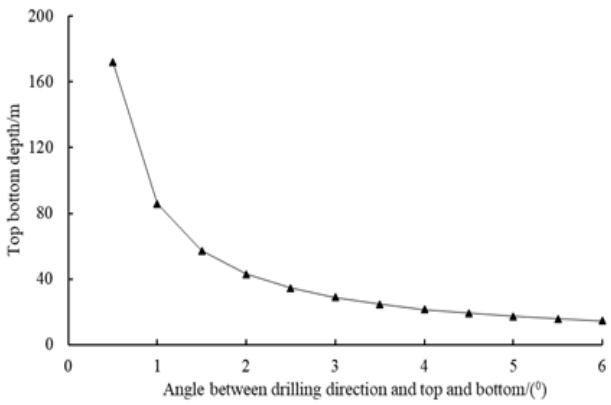

Figure 4 Relationship between drilling depth and opening direction

It can be seen from Figure 4 that the peak drilling depth of the drill bit has a great relationship with the adjustment angle of the rig. With the increase of the angle between the drilling direction and the top and bottom, the peak depth of the drill bit has a tendency to decrease rapidly and then slowly. However, in actual operation, it is very common for the rig angle to differ by 1 to 2 degrees. In addition to the sinking of the rig and the change in the direction of the borehole, when the drill bit encounters the top or bottom plate, the impact is mainly manifested in the following aspects.

(1) The drill bit is drilled along the top or bottom plate. In general, it is difficult for the drill to enter the roof. After drilling and encountering the roof, the drill rod will change the original drilling direction and drill along the roof. The drill rod forms an inflection point at the point where it enters the roof, and the drill rod is subjected to "alternating bending stress" at the inflection point. Alternating bending stress, it increases the torque of the rig and may also cause the drill pipe to break.

(2) The drill enters the top and bottom plates. It is not uncommon for the drill to enter the roof. When the angle between the drilling direction and the roof is large, or the roof is uneven, the drill enters the roof and causes the drill rod to bend strongly. In this case, the drilling must be stopped.

5. EFFECT OF IN-HOLE COAL CANNON ON DEEP HOLE DRILLING

In the process of drilling outburst coal seams, small coal and gas outbursts often occur in boreholes. Coal cannon refers to the loud noise accompanying coal and gas in the borehole. Outburst coal seams have high gas pressure and high gas content. The energy stored in the coal body is partially released during drilling. During the energy release process, the coal body around the borehole suddenly expands and destabilizes, and the gas carries the coal body (coal slag) pours into the borehole. Excessive coal slag completely or partially blocks the borehole, which increases the resistance to rotation of the drill pipe, and the slag discharge channel of the borehole is completely blocked or partially blocked. There are several types of coal cannons, which have different degrees of impact on drilling. There are the following situations:

(1) Intermittent small coal cannon. Intermittent small coal cannons are small coal cannons that occur over a long period of time, and there is no relationship between each other or reaction chain. As long as necessary drilling measures are taken, the impact of intermittent small coal cannons on deep hole drilling can be avoided. When the small coal cannon occurred, the amount of cinder production increase, but it is not enough to completely block the borehole, and the slag drainage system of the borehole could still barely work. In this case, the driller is required to temporarily stop the rig from advancing forward, and keep the drill pipe continuing to rotate and slag discharge. At the same time, adjust the maximum feed pressure of the drill to reduce it. When the situation improves completely, continue to move forward normally.

(2) Continuous small coal cannon. Continuous small coal cannon refers to the short interval between coal cannons, such as several seconds, ten seconds, etc. This type of coal cannon has a great influence on deep hole drilling in protruding coal seams. When encountering this type of coal cannon, the drill pipe needs to be retracted immediately to prevent the drill pipe from being “locked

up", and then slowly drilled forward again with enhanced slag discharge. After the continuous small coal cannon occurs, a large range of loosened area will be formed around a certain section of borehole. The loosened area will be converted into a hole collapse area when drilling again. It is difficult to form a hole after the drill rod enters this area. The wind will open a new slag discharge channel at the top of the hole collapse area. At this time, the energy in the coal body has been released and can continue to drill forward.

(3) Sudden big coal cannon. In rare cases, coal cannons with loud noises can be heard suddenly or without obvious signs. After the big coal cannon occurred, the rotation resistance of the drill pipe increases sharply, and the drill pipe must be retracted immediately. In many cases, the drill pipe is locked and the drill stops rotating. After the rig stops rotating, you must immediately change the high-speed gear to the low-speed gear, continue to operate the rig, and perform rotary lifting. The above operations are effective in individual cases, and improper handling will cause missing drills. The big coal cannon is a stumbling block for deep hole drilling in protruding coal seams. At present, there is no absolutely effective method to solve it.

In short, drilling coal cannons are one of the main factors affecting deep hole drilling. Nozzles and "drilling holes" also have a certain relationship with coal cannons. Before the occurrence of coal cannons, there are often certain precursors: the drilling deformation increased, and the rotation resistance of the drill pipe increased. Therefore, rig operators need to observe carefully, catch the signs before the occurrence of coal cannons, and prepare for the coal cannons in advance.

6. CONCLUSION

Combined with on-site experience and theoretical analysis, the detailed analysis and research are conducted on the influencing factors of deep hole drilling in soft outburst coal seams, which mainly include the estimation of the situation inside the hole after severe blowout and its effect on deep hole drilling, the effects of deep hole drilling, the effects of top and bottom plates on deep hole drilling, and the effects of coal cannons on deep hole drilling. It is pointed out that the drilling encounters the top floor and the drilling coal cannon are the key factors affecting the deep hole drilling.

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