The Advantage of 3D Design of Mine Gas Drainage Borehole

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Abstract. Coal and gas outburst is the sudden release of in-situ stress, and the release intensity is beyond people's control. The measures to prevent and control coal and gas outburst are to build a safety barrier for the mining and excavation face by means of prevention and control engineering, construction of gas drainage borehole, artificial release of ground stress or reduction of the sudden high-intensity release of underground potential damage energy. The design of coal mine gas drainage boreholes under two-dimensional and three-dimensional conditions will be quite different. Through comparison, it can be seen that the borehole design based on three-dimensional modeling can play a better role in prevention and control of coal and gas outburst.

1. Introduction
The essence of coal and gas outburst is the sudden release of some potential energy underground, and the release intensity is beyond people's control. The essence of outburst prevention and control measures is to eliminate or reduce the potential underground energy and destroy the conditions of sudden high-intensity release of energy through prevention and control engineering and construction of gas drainage and drilling holes, so as to build safety barriers for mining working faces.

Coal mine gas drainage drilling is a massive project. According to statistics, the total length of gas prevention and control boreholes constructed every year in China can rotate around the equator of the earth for more than one week. At present, in the design of gas drainage borehole, the seepage theory method is used to determine the effective drainage radius of the borehole. Then, with reference to the effective radius, the holes on the roof of the coal seam are arranged at a certain distance and equal spacing to ensure that the effective extraction range of the holes is evenly distributed in the plan and profile. As shown in Figure 1.

Figure 1. Drilling design drawing in 2D
It seems reasonable to observe the distribution of boreholes only from the plan, but it can be seen from the section that the density of boreholes in the upper side of the coal roadway to be dug is rare, and the density of boreholes in the lower side of the coal roadway to be dug is dense.
As shown in Figure 2, it can be seen from the profile that the thickness of the coal seam has a great influence on the design of the drilling hole according to the current design requirements. The thicker the coal seam is, the smaller the minimum intersection angle between the drilling hole and the coal seam is, and the longer and denser the drilling hole is at the lower side of the roadway to be excavated. In the field construction, the dense local drilling may increase the safety risk. The hole under construction is easy to collide with the completed hole in the hole. Once the holes with low angle and post construction are connected with the completed holes, it is difficult to reach the design depth. This kind of design will inevitably bring great hidden danger to safety production.

According to the basic principle of drilling, a deeper hole cannot be drilled without discharging the drilling slag. The medium (wind or water) for slag removal in the drilling hole under construction is easy to leak from the completed drilling hole. The leakage of slag removal medium reduces the velocity of slag removal medium in the drilling hole and the capacity of slag removal. As a result, large particles of coal dust will accumulate, and the accumulated drilling slag will hinder the rotation of the drill pipe and friction the drill pipe to generate heat. If it is found that the treatment is not timely, it is very easy to cause accidents of broken drill pipe and burning drilling tools (or fire in the hole), which is very dangerous.

The following conclusions can be drawn: If only the design of arranging the coal seam roof points evenly in the two-dimensional plane is considered, the space between each borehole and the coal seam roof points is equally arranged from the plan and section. Considering the influence of its own weight, the outburst risk of the upper side of the roadway to be excavated is relatively high, but the density of borehole in the designed upper coal body is rare. Considering the its own weight, the outburst risk of the lower side of the roadway to be excavated is relatively low, and the borehole density in the designed upper coal body is rather dense. The design of deep and long drilling holes in thick coal seam is easy to cause local dense piles, which not only makes the drilling construction difficult, but also increases the
amount of ineffective drilling work. This design will not only cause part of the project cost waste, but also increase the safety risk of coal mine and reduce the treatment effect.

To extract coal seam gas is to solve the problem of gas extraction in coal body, which is a three-dimensional space design problem. According to the principle of extraction radius, when the borehole axis is vertical to the coal seam surface, its effective extraction range should be a cylinder in the coal body. When the borehole axis is not vertical to the coal seam surface, its effective extraction range should be an irregular cylinder in the coal body. When the borehole axis is parallel to the coal seam surface, its effective extraction fan should be an irregular rectangle. As shown in the figure 3.

![Figure 3. Drawing range of different drilling angles](image)

In the three-dimensional design of gas drainage drilling. The effective (designed) extraction radius of drilling holes in the same location, same or similar extraction time, same hole diameter, same construction and extraction technology can be regarded as the same. Restricted by the underground space conditions, the angle between the borehole and the coal seam surface is different, and the thickness of the coal seam is different. Each borehole for the underground coal seam gas extraction takes the axis of the designed borehole as the center and the radius of the designed extraction radius as the radius, which will form various forms of irregular columns, and realize the seamless filling of the above irregular bodies in the coal body.

According to the principle of extraction radius, it is necessary to realize that the distance between any coal particle in the control range of the borehole and the axis of the borehole is less than or equal to the design extraction radius. In order to ensure the uniform distribution of boreholes in the coal body, and to avoid the superposition of multiple boreholes to the maximum extent, it is required that the distance between the total coal body particle and the axis of the adjacent boreholes is the same as the design extraction radius. According to the theoretical analysis, only when the thickness of coal seam is zero, the layout of drilling engineering points in 3D design and 2D design is the same.

It is assumed that the thickness of the coal seam at the proven design section of a coal seam is 10m, the inclination of the coal seam is 15 °, the horizontal distance between the bottom rock roadway and the coal roadway to be excavated is 35m, the height of the coal seam floor in the coal roadway to be excavated is 2m higher than the bottom rock roadway, the width of the coal roadway to be excavated is 4m, the width of the bottom rock roadway is 4m, and the design extraction radius of the borehole is 5m. The gas drainage boreholes are designed in two-dimensional and three-dimensional respectively. The plan and section of the design sketch are shown in Figure 4.
In the design of two-dimensional space, the section map is drawn manually and the relevant parameters are measured. According to the current requirements of gas drainage, a total of 10 boreholes need to be designed and constructed, with a total work volume of 615m. The design in three-dimensional space is also arranged according to 10 boreholes, and the total drilling work is about 540 meters. The design in two-dimensional space is more obvious for thick coal seam, extra thick coal seam, especially the thick coal seam or extra thick coal seam where the drill hole intersects the coal seam surface at a low angle.

The design of three-dimensional space with equal spacing avoids the dense pile-up of boreholes in local areas, reduces the risk of burning, breaking and holding drilling accidents caused by the collusion of boreholes in local areas from the design source. The spatial distribution of boreholes in the coal body is more reasonable, the density of boreholes on the upper side of the roadway to be excavated is more dense, the control range is larger, the number of boreholes is the same, and the total work quantity is larger than that in two-dimensional space 12% design savings.

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