Practice of outburst prevention by pre-driving rock roadway unloading pressure of coal roadway strip in Fengcheng mining area

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Abstract. In view of the new characteristics of the coal and gas outburst disaster of single serious outburst dangerous coal seam in the deep mining area of Fengcheng mining area, the article puts forward regional outburst prevention measures of unloading pressure by pre driving rock roadway and constructing wear layer drilling to pump coal roadway strip gas, a complete set of technical system of regional outburst prevention in coal roadway strip by pre driving and unloading floor roadway in the Fengcheng mining area is obtained. The field practice shows that after entering the deep mining stage, under the conditions of high stress, high gas, high temperature and low permeability, the situation of outburst occurrence is more and more serious, and the mechanism is more complicated, although coal roadway of B4 coal seam has taken the measure of construction of drilling for pre pumping gas along B4 coal seam, but the damage of the high ground stress has not been completely eliminated, the proportion of in-situ stress dominated outburst is increased. Regional outburst prevention is carried through pre driving of floor roadway layout in the rang of 8~12m which just below the coal roadway to carry on the pressure relief combined with crossing drilling drainage gas., it can greatly improve the permeability of coal seam and the effect of pressure relief, and ensure the safe and fast roadway driving.

1. Introduction
Coal mining is experiencing the process of mining conditions from shallow to deep, from simple to complex and significantly increased the level of mining technology, deep coal rock mass under the conditions of high stress, high gas pressure and high temperature, its mechanical characteristics are different from that of shallow coal rock, such as the stress of surrounding rock in deep coal rock deformation and the strong field evolution of complex and diversity, rock rheology characteristics, the brittleness ductility transformation, the dynamic response of mutant[1-3]. In addition, with the popularization of intensive mining technology, the working face mining speed is increased, the plastic strain energy consumption of coal and rock mass near the working face is reduced, and the elastic energy of surrounding rock can accumulate to form high energy level; The engineering force and the external
induced energy are also significantly increased, which in a certain extent increased the risk of coal and gas dynamic disasters [4-5]. The mechanism of coal and gas outburst is more complicated and the difficulty of disaster management is increased, and the related basic theory research can not meet the needs of engineering practice. Therefore, with the increase of mining depth and the change of mining conditions, the outburst and other dynamic disasters need to be recognized and studied.

2. Engineering survey and analysis of outburst characteristics of coal roadway driving

2.1. Engineering survey

Fengcheng Mining Bureau is located in Shangtang town on the north of Fengcheng City, mining area across the 5 towns of Qujiang, Shangtang, Shangzhuang, Meilin and Tuochuan, northeast southeast direction length is 26km, width is 13km, the area is 338km². Fengcheng mining area in 1955 made a formal exploration, design and construction, currently owned mine have entered the deep mining (vertical 650~1000m), which is the elevation of -750m in Shangzhuang coal mining in shallow coal seam; Qujiang company is mining the deep coal seam of Pinghu mine and Jianxin mine, its production elevation is -850m.

The geological structure of Fengcheng mining area (Qujiang, Jianxin and Shangzhuang) is relatively simple, the single B4 coal seam of the main mining is relatively stable, coal thickness is generally between 1.7~2.4m, the largest coal thickness is up to 4.0m; Coal seam from south to north is inclined angle, generally between 8~23 degrees, dip angle of shallow coal seam is large, dip angle of deep coal seam is small; The deepest part of deep coal seam in Qujiang syncline, Shishang syncline is nearly horizontal. The mining area is one of the serious coal and gas dynamic disasters in the whole country, the gas pressure is high in B4 coal seam (Qujiang company measured Pmax=9.2MPa), coal seam gas content is high($W=13.5~25.3m^3/t$), this coal seam is soft, it was once the gas disaster occurred frequently in the hardest hit in the history, there have been many gas explosion and 186 prominent outburst, The outburst depth of 325m from the beginning, the biggest highlight the strength of 1390t and gas outburst amount of 1 million 620 thousand m³.

2.2. Analysis on outburst characteristics of coal roadway in mining area

After entering the deep mining stage, under the conditions of high stress, high gas, high temperature and low permeability, the situation of outburst occurrence is more and more serious, and the mechanism is more complicated; Although the coal seam has taken the measure of the coal seam gas pre drainage, the energy of the gas is reduced, but the damage of the high ground stress has not been completely eliminated; Under the condition of insufficient pressure relief, even in the local area to add advanced drilling, but it could still happen in-situ stress dominated outburst.

(1) Outburst distribution has regional characteristics, in the north east of the mining area, the outburst occurred more in the end region of the stress concentration, coal seam occurrence change sharply, fault comparative development and geological structure, and the coal seam gas occurrence is more concentrated, the gas content is bigger.

(2) The type of outstanding type is complete, with the increase of mining depth the proportion of in-situ stress dominated outburst is increased.

(3) Most of outburst occurs with gas emission increased, temperature decreased, rib spalling, bulging, outer drum of coal wall, crown drill, jamming of a drilling tool, orifice drilling and other obvious signs, but also had no obvious signs of a prominent macroeconomic occur outburst, the coal seam of the working face is hard and has no soft layer when the outburst is not prominent.

(4) The outburst is closely related to the geological condition, most of outburst occurred in the process of coal roadway driving

(5) With the increase of mining depth and increasing mining intensity, Fengcheng mining area and the other area (such as the Chongqing area, Huainan mining area etc), the phenomenon of abnormal gas powered by in-situ stress as the leading role has been occurred, such as the working face of the outburst
hazard prediction or measures to test the effect of inspection indicators are far less than the relevant provisions and standard reference index but it occurs outburst.

(6) The mine entered the stage of deep mining, mining face were taken to the regional gas drainage and local comprehensive outburst prevention measures, reduce the gas outburst potential, the main factors of mine gas prominent frequency decreased, but in-situ stress dominated outburst increased.

3. Analysis of outburst prevention principle and the reasonable position of the pre driving floor roadway

3.1. The principle of pressure relief and outburst prevention by pre driving floor roadway

The coal and rock mass in the deep high stress environment is in the post peak characteristic state, there may be complex stress zone in roadway surrounding rock, the state of roadway surrounding rock under certain conditions sometimes occur the case of alternating between the expansion and compression zones, and the geometric size (width) by a geometric series increase, and it will appear the phenomenon of regional breakdown; The peak of roadway surrounding rock stress is weakened, and the width of pressure relief zone increases significantly, as shown in Figure 1.

Figure 1. Schematic diagram of non peak stress distribution in partition failure of roadway surrounding rock

In the deep tunnel, there are a number of rupture zones, the surface of the roadway to the outside boundary of the most lateral rupture area, which is the pressure relief radius of the roadway. Assuming the most lateral rupture zone is i, the expression of the inner and outer boundary of the ith rupture zone is:

\[ R_i = R_{i-1} \times \left[ \frac{\nu(3-2\nu)(1+\nu)P_0 + (1-\nu)\sigma_i}{(\sigma_{i-1} - \sigma_i)(1-\nu)^2} \right]^{\frac{1-\sin \varphi}{2 \sin \varphi}} \]  

(1)

\[ R_e = R_i \times \left[ \frac{3}{-12(3-2\nu)(1-\nu)(\sigma_i^2/P_0 - \nu^2(2\nu - 1))} \right]^{\frac{1}{4}} \]  

(2)

The index of \( R \) and \( P \) indicates the number of the rupture zone; \( i \) represents the inner boundary of the rupture zone; \( e \) represents the outer boundary of the rupture zone; \( \nu \) represents material Poisson's ratio; \( P \) is the original rock stress.
To sum up, because of the large difference between shallow mining and deep mining in the mining area, there is a difference in the width of the unloading zone around the roadway surrounding rock. In the deep mining, the stress level is higher, and there may be a zonal disintegration phenomenon in the vicinity of the surrounding rock, and the width of pressure relief zone increases obviously.

3.2. Analysis on reasonable space position of bottom roadway

The stress field distribution of the bottom plate after mining face is shown in Figure 2. The vertical stress distribution in the condition of different horizontal b and vertical distance h is shown in Figure 3.

![Figure 2. The stress distribution curve of the overlying coal seam after the roadway driving](image)

![Figure 3. Schematic diagram of surrounding rock stress distribution after mining](image)

Staggered arrangement is a relief zone formed in the working face after mining, outside arrangement is located in the plenum area. The floor roadway and coal roadway with staggered arrangement, with floor roadway and roadway horizontal distance increases, the influence of coal roadway driving on the left side of floor roadway is great, the influence on the bottom floor and the right side of the floor roadway is small, but the effect of pressure relief of coal seam on the top floor roadway is decreased, together with the influence of the support pressure on the dynamic pressure of the bottom plate roadway during the process of coal roadway driving. Therefore, with the increase of the flat distance of floor roadway and the coal roadway, the position of the bottom plate is not conducive to the maintenance of the roadway and implementation of pressure relief and outburst prevention measures. Floor roadway and coal roadway with outside arrangement also has the above shortcomings.

When the distance between the surrounding rock and roof of floor roadway is larger than 15m, the surrounding rock stress of roadway is close to or reach the original rock stress, and the effect of pressure relief is not obvious. In the "Regulations for prevention of conflict", when the outburst coal seam is adopted to take the regional outburst prevention measures, it should be implemented before the minimum normal distance from the coal seam to 7m. Considering the complexity of the coal seam, prevention of coal seam occurrence mutation and the situation of it is not in time to take the regional outburst prevention measures, if it adopted regional outburst elimination measures mainly by the construction of crossing drilling in floor roadway to pre pumping coal roadway trip gas, Minimum direction distance floor roadway from coal seam should be not less than 8m. Comprehensive analysis shows that: the reasonable position is the normal distance between the floor roadway and the coal seam floor in the range of 8~15m, which is overlapping arrangement with coal roadway. With the increase of
mining depth, dip angle of coal seam and roadway section, the floor lithology is soft, the effect of floor roadway on the unloading pressure of the overlying coal roadway strip is increased; Based on the current mining level of Fengcheng mining area, the floor roadway should be arranged in the range of 8~12m which just below the coal roadway to be excavated.

4. Analysis on the effect of outburst prevention measures in pressure relief drainage area of coal roadway strip

4.1. Effect of strip extraction in coal roadway

Figure 4 shows crossing drilling gas pumping concentration curve and scalar curve of Qujiang company, Shang Zhuang mine, Jianxin mine, the concentration of the mixed gas from drilling drainage in the whole roadway is the maximum of 13%, the amount of daily gas drainage is up to 580~3200m³/d, gas drainage is relatively uniform, the extraction effect is remarkable.

![Figure 4. The variation curves of gas concentration and pure quantity in the test roadway](image)

Qujiang mine, Shangzhuang mine, Jianxin mine in Fengcheng mining area, there are 5 coal roadway outburst prevention measures by the combination of floor roadway pressure relief and gas pumping, the pumping effect is significant after floor roadway pressure relief, the highest gas pumping rate is 32%~58%, the residual gas content is approaching 2.67~5.48m³/t after the pumping of 86~135d, far
lower than that of 8m³/t, it realizes the outburst of coal roadway in the coal mining area, which provides a guarantee for the safety of coal roadway.

4.2. Verification of outburst prevention effect in Coal Roadway

After the effective test of regional outburst prevention measures in testing roadway, the tunneling verification was carried out for coal roadway to be excavated, and the local outburst danger in the process of coal roadway driving was predicted.

Shangzhuang mine 710 and 505 crossheading after taking outburst prevention measures by the combination of floor roadway pressure relief and gas pumping, local outburst risk prediction indices were small, the $K_1$ value of gas desorption index of drilling cuttings is between 0.08~0.43ml/g·min$^{1/2}$, the $S$ value of drilling cuttings content is between 2~4.7kg/m, these are less than the critical value 0.5ml/g·min$^{1/2}$ and 6kg/m, it realizes the safe and fast development of coal roadway.

Qujiang mine 702 and 213 crossheading after taking outburst prevention measures by the combination of floor roadway pressure relief and gas pumping, local outburst risk prediction indices were small, the $K_1$ value of gas desorption index of drilling cuttings is between 0.08~0.65ml/g·min$^{1/2}$, the $S$ value of drilling cuttings content is between 2~4.2kg/m, these are less than the critical value 0.7ml/g·min$^{1/2}$ and 6kg/m, it realizes the safe and fast development of coal roadway.

Jianxin mine 1128 crossheading after taking outburst prevention measures by the combination of floor roadway pressure relief and gas pumping, local outburst risk prediction indices were small, the $K_1$ value of gas desorption index of drilling cuttings is between 0.11~0.45ml/g·min$^{1/2}$, it is less than the critical value 0.5ml/g·min$^{1/2}$, it realizes the safe and fast development of coal roadway.

5. Main conclusion

In the serious outburst coal seam, selecting the appropriate location in the bottom of the roadway to be driven, through the coal roadway strip for pressure relief and gas pumping to realize the purpose of regional outburst prevention.

With the increase of coal seam inclination, the vertical stress and shear stress of floor rock roadway surrounding rock are gradually reduced, the plastic zone of roadway surrounding rock and the deformation of surrounding rock are gradually increased, and the pressure relief degree of floor rock roadway was gradually increased; With the increase of lateral pressure coefficient, floor rock roadway vertical stress decreases and the shear stress increased, while the plastic zone of surrounding rock decreases, but the deformation of surrounding rock increases, pressure relief degree of floor roadway roof increased gradually; With the increase of the depth of the coal seam, the vertical stress and shear stress of the surrounding rock are gradually increased, the plastic zone of surrounding rock and the deformation of surrounding rock are gradually increased. When floor roadway is located just below the coal roadway (crossheading), floor rock roadway has a good effect of pressure relief, and it has little influence on both sides of roadway.

After entering the deep mining stage, under the conditions of high stress, high gas, high temperature and low permeability, the situation of outburst occurrence is more and more serious, and the mechanism is more complicated; Although coal roadway of B4 coal seam has taken the measure of construction of drilling for pre pumping gas along B4 coal seam, but the damage of the high ground stress has not been completely eliminated, the proportion of in-situ stress dominated outburst is increased; Regional outburst prevention is carried through pre driving of floor roadway layout in the rang of 8~12m which just below the coal roadway to carry on the pressure relief combined with crossing drilling drainage gas,, it can greatly improve the permeability of coal seam and the effect of pressure relief, and ensure the safe and fast roadway driving.

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