Outburst prevention and control technology of thin coal zone in island coal face with potential outburst

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Abstract

As for coal seam feature, geological structure and mining face stress concentration, the thin coal zone in island coal face with potential outburst is liable to induce dynamic disaster, such as coal and gas outburst, rockburst. It can improve the safety level and resource recovery ratio to research the outburst control technology of thin coal zone in island coal face. 11061 mining face of Liangbei mine is an island coal face, and the coal seam has outburst danger. When 11061 coal face exposed the thin coal zone unexpectedly, the strata behaviours were so serious that the coal face was forced to stop mining. Based on the distribution characteristics and stress regularity of the thin coal zone, the comprehensive outburst prevention and control technology which consists of pressure-releasing drill, loosening blast, discharging drill and effect check has been found and used in the thin coal zone. The results has proved that the comprehensive outburst prevention and control technology is effective to remove the outburst danger of the thin coal zone in 11061 mining face, and the comprehensive technology can help to mine 11061 coal face continuously in spite of the thin coal zone, which has brought successful engineering experience and distinct economic benefit.

Keywords: outburst coal seam; island coal face; thin coal zone; loosening blast; effect check

1. Introduction

The surrounding places of the island coal face are goaf areas, so the island face and its roadways are liable to form the stress concentration zones during mining, which can lead to the drastic roof movement and the serious roadway deformation [1,2]. Considering the influence of geological structure and coal
seam occurrence feature, the thin coal zone in island coal face with potential outburst is most dangerous, because there can occur coal and gas outburst or rockburst, which has threatened the safety of the operation worker in the island face. Nowadays, the study about island coal mainly focus on the stress regularity of working face, stability and control of mining roadways [3,4]. The study about outburst control mainly focus on the regularity outburst control technology of excavating face or mining face [5-8], and the study about thin coal zone mainly focus on detecting and mining technology[9]. But the outburst control technology of thin coal zone of island face has hardly ever been studied. As for development of mining depth, influence of geological structure and mining face succession, the thin coal zone of island face is difficult to avoid. To research the outburst control technology of thin coal zone of island face with potential outburst, there can gain important engineering experience and reality value in the similar conditions.

Liangbei coal mine of Shenhuo Group Co. Ltd. is situated at Yuzhou city Henan province, whose design production capacity is nine hundred thousand ton every year. Liangbei coal mine was identified as a coal and gas outburst mine in 1999, and it has already occurred some outbursts and rockburst and so on during mining period. 21 coal seam is the main mining seam, which is under Shanxi formation Permian. The average thickness of 21 coal seam is 4.18 meters, and its angle is on the range of 8-15°. It is a low air permeability coal seam, and the strength coefficient is 0.15-0.25. The coal seam destruction type of 21 coal seam are III and IV. 11061 mining face is the second section of the west district, whose length in trend is about 740 meters, and the length in inclination is 112 meters. All the haulage entry, return airway and open-off cut are drove along with the top of 21 coal seam. It adapts retreating fully mechanized mining method. The above of 11061 mining face is 11041 goaf areas, and the blow of 11061 mining face is 11081 goaf areas, which is a typical island coal face. When 11061 coal face starts to mine, it uses “long drill drainage in mining roadway (haulage entry and return airway) +short borehole drainage in working face” outburst control method. While 11061 mining face moves forward 110 meters from the open-off cut, there exposes the thin coal zone unexpectedly, and it has critically influenced the production of 11061 mining face.

2. Distributional characteristics and possible solution of the thin coal zone in 11061 face

The thin coal zone lies in the middle of 11061 working face. The length of the thin coal zone is in the range of 40-60 meters, and the minimum thickness is only 0.3 meters. Use radio-wave penetration method to explore the thin coal zone, and the distribution of thin coal zone is shown as figure 1. Section A whose thickness is less than 1 meter is about 60 meter in inclination (about half the whole inclination length of 11061 working face) and the trend length is about 50 meter, and section A is so thin that it influences severely the working face to mine. The thickness of section B is less than 2 meters, which has some influence on the working face. The thickness of section C is more than 3 meters, which has little influence on the working face.

The figure 2 shows the variation charts of the hydraulic supports resistance of the thin coal zone in 11061 mining face. From the figure we can see, when the working face exposes the thin zone, the hydraulic supports working resistance (the diagram of elliptic region) increases significantly, some hydraulic supports’ working resistance value has reached or exceeded the safety limit value of hydro-cylinder (37.5MPa). In addition, there comes frequently some coal loud guns in the thin coal zone, the outward movement of coal wall and rock stratum has amounted to 20-90mm. Therefore, the thin coal zone has not only seriously influenced the normal mining face forward, but also may induce dynamical disaster, such as coal and gas outburst or rockburst, so should inflict personal injury.
To ensure the 11061 mining face safety, considering the thin coal zone distribution and the working face features arrangement, then we propose two solutions: ① re-excavate a new open-off cut and move working face to avoid the thin coal zones; ② use comprehensive outburst control technology and continue to mine the 11061 working face. Compare the two solutions and find that option 1 has the advantages of higher security, but to re-excavate a new open-off cut and to move equipment of working face will consume more time, influence production and waste coal resources. Option 2 has the virtue of a full recovery of coal resources, maintaining mine production, accumulating the successful experience for such a situation that may meet in future, but continuing to mine in the thin coal zone has a higher risk. According to the advantages and disadvantages of the two solutions, combined with 11061 mining face rock features, characteristics and occurrence of thin coal zone island status, the final selection is option 2, that is to adopt a comprehensive outburst control technology and continue to mine 11061 working face.

### 3. Comprehensive outburst control technology of the thin coal zone

The thin coal zone control technology follows the rule of “to release pressure beforehand and to transfer the higher stress into the deeper position”, which includes the area outburst control technology and the local outburst control technology. First, the area outburst control technology is used. Then, the local outburst control technology will be taken. The area outburst control technology mainly consists of bed-parallel drills in the mining entries, assisting with front drills in the working face. The local technology consists of loosening blast and discharge drill in the thin coal zone. The comprehensive outburst control technology system of the thin coal zone in 11061 mining face is shown in figure 3.
3.1 Area outburst control technology of thin coal zone

11061 mining face thin coal zone comprehensive outburst control technology mainly are: inclination bed-parallel drills in conveyer entry and return airway, trend front drills in working face. Every circular distance of area outburst control is 50m, while the advance protection distance is 30m.

The pressure-releasing drills of return airway are placed at roadway underside, while the drills of conveyer entries are placed at roadway upside. Usually, the pressure-releasing drills are accomplished by high power hydraulic drill machine, and the range of pressure-releasing dills is in the front of the working face within 50m. The opening position of drills is 0.3-0.6m under the roof, and drill diameter is φ75 mm. Drill hole interval distance is 0.7m, and drill angle goes with the roof angle, designed depth of borehole can’t be less than 65m(including the length through waste rock).

There are the trend front-detecting drills to probe the front coal body and the thin coal zone distribution in the thin coal zone of working face, and the front-detecting drills’ depth should be more than 50m to ensure an advanced distance of 30m. The front-detecting drills are constructed under hydraulic supports, and one front-detecting drill every hydraulic support. The drill hole is 1.2m below the roof, perpendicular to coal surface, with inside diameter φ75 mm and depth 50m. At the same time, one drill through strata is placed every hydraulic support in the thin coal zone, and the drill hole is 1.5-2.0m below the roof, perpendicular to coal surface, with diameter φ75 mm and inclination +1-1.5°.

3.2 Local outburst control technology of thin coal zone

After area outburst control measures passing effect check, take the following local outburst control technology: loosening blast in the thin coal zone, outburst control discharging drill. Every circular distance of local outburst control is 12m, while the advance protection distance is 9.5m.

After explosive exploding in the coal and rock, there will form crushing zone, crack zone and shock zone around the shot hole. Because coal and rock of crushing zone and crack zone have changed in
structure, the two zones will have a vital function on local outburst control. As for cylindrical explosives, the radius of crushing zone is generally 2 to 3 times than that of powder charging, the radius of crack zone can be calculated using Equation 1.

\[
R = R_0 \left( \frac{\mu}{1 - \mu} \cdot \frac{P}{s} \right)^{\frac{1}{3(\mu)}}
\]

Where \(R\) = radius of crack zone; \(R_0\) = radius crushing zone; \(\mu\) = coefficient lateral pressure; \(P\) = peak pressure of explosion wave; \(s\) = tensile strength of coal or rock.

by Equation 1, the loosening blast parameters of the thin coal zone in 11061 mining face are as follows: drill hole diameter \(\phi 42\) mm, drill interval distance 3m, hole depth 10m, drill layout under the coal seam about 1.8-1.9m, with yellow mud sealing, sealing of holes depth of 5-6m, in series connection mode, one time detonation process.

Outburst control discharging drill hole in thin coal zone is 12m in depth, and drill hole diameter is \(\phi 75\)mm. According to the different thickness of coal, gas discharging holes change from 1 to 5 rows respectively. ① When the thickness of thin coal zone \(\leq 0.3\)m, 1 row of discharge holes, holes below the roof 150mm, level hole spacing 210mm. ② When \(0.3 < \) the thickness of thin coal zone \(\leq 0.8\)m, 2 rows of discharge holes, three flower arrangement, hole spacing 420mm, pitch 200mm, the first row holes below roof 150mm, the first and second rows horizontal holes. ③ When \(0.8 < \) the thickness of thin coal zone \(\leq 1.5\)m, 3 rows of discharging holes, three flower arrangement, hole spacing 420mm, pitch 400mm, the first row holes below roof 300mm,The first and second rows horizontal holes. ④ When \(1.5 < \) the thin coal thickness \(\leq 2.5\)m, 5 rows of discharging holes, the first ,fourth and fifth row spacing of 1500 mm, the second and third-row spacing of 750mm, pitch 200 mm, the first row of holes(the top row of holes) below the roof 1.3m; ⑤ When the thin coal zone thickness> \(2.5\)m, 5 rows of discharging holes, spacing 1500 mm, pitch 200 mm, the first row holes (the top row of holes)below the roof of 1.8m.

3.3 Effect check of comprehensive outburst control technology

After area outburst control and local outburst control carried out in thin coal zone, only the effect check of outburst control has passed through, can the working face be mined. Each cycle of the area outburst control measures permits mining face forward 20m, while the advance protection distance is 30m. Each cycle of the local outburst control measures permits the face forward 2.5m, while the advance protection distance is 9.5m. Figure 4 is drill cuttings volume comparison before and after loosening blast in thin coal zone.

![Fig. 4. Influence of loosening blast on drill cuttings volume](image)

Figure 4 shows that the loosening blast has a distinct influence on drill cuttings volume. Before loosening blast, the amount of cuttings gradually increases in space drill depth increase. After loosening
blast, the amount of cuttings reduces. Especially, the amount of cuttings in drill 4-8m depth position reduces significantly, and it reduces by 40% to 70%. These show that loosening blast makes the coal structure a significant change, and makes the stress distribution within the coal changes too.

In addition, according to the work resistance of hydraulic supports in thin coal zone before and after outburst control measures, the change reflects the effect of pressure-releasing in thin coal zone, as shown in Figure 2, after the outburst control measures, the work resistance of hydraulic supports in thin coal zone reduces rapidly, and the high stress zone in thin coal zone transfers to the deep coal. This shows that comprehensive outburst control technology has acquired a remarkable engineering effect.

4. Conclusions

After the comprehensive outburst prevention and control technology had been put into practice in 11061 mining face, the 11061 coal face has mined continuously by means of drilling and blasting method to excavate the gangue of the thin coal zone. Nowadays, the mining face has gone through the thin coal zone safely and successfully, the comprehensive technology has not only brought distinct economic benefit in 11061 coal face, but also gotten successful engineering experience to mine safely in the similar conditions.

(1) Due to the influence of geological structure in the thin coal zone, 11061 island mining face has some high stress concentration areas and serious strata behaviours, so can induce outburst or rock burst suddenly.

(2) The comprehensive outburst prevention and control technology includes the area outburst control technology and the local outburst control technology. The area outburst control technology consists of pressure-releasing drill in two mining roadways and front-detecting drill in mining face; moreover, the local technology consists of loosening blast and discharging drill in mining face. After the comprehensive technology had been used in 11061 island face, the effect check was better, and the coal face can be mined continuously.

(3) The effect of the comprehensive technology in the thin coal zone proves that pressure-releasing drill, loosening blast, discharging drill and so on has successfully eliminated the outburst danger of 11061 coal face by changing the structure and stress distribution of the thin coal zone, which has gained ideal results in 11061 island face.

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