Effects of Geologic Condition to Mine Gas Distribution and Control Measures

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Abstract

By analyzing the geological exploration data and actually monitoring gas data of the Jiangjiahe coal mine in Binchang mine area, preliminary summarized geological conditions affecting the mine high gas distribution, such as sealing effect of the coal seam roof and floor mudstones, a high-pressure zone of the fold axis and climbs stress concentration sections, and mining area have not experienced a strong geological evolution, inertinite and vitrinite high content, low coal rank, slowly flowed groundwater and deeper buried depth, and also combined with the gas largely emission characteristics in ZF1404 coalface (i.e. central syncline), adopted the integrated measures to control coal gas, such as set out air brattice in up corner of coalface, and high pressure air channel, and rigidity drainage pipe the gob of the neighbor coalface, increase air quantity of coalface, and construct high position drill shack to drain the gas from the neighbor coalface in advance, construct across drill hole to drain the gas from the working seam in advance. These control measures acquired favorable effects to control the gas of ZF1404 coalface of Jiangjiahe coal mine.

Key words: Bin-chang mining area; Jiangjiahe coal mine; gas; geologic condition; control measures

1. Introduction

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Jiangjiahe coal mine, being under construction, belongs to Bin County Coal CO, LTD of Shaanxi Province. And its design production capacity is 0.9Mt/a. It is located in the south edge of Binchangmining area, whose north boundary lies to Large Buddhist Temple coal mine, and the boundary is the seams zero line in the west, east and south. As far as geological structure is concerned, Jiangjiahe coal mine is located in the south of Bin county anticline and the north of Taiyu anticline depicted in Fig.1. The 4# coal is available mining coal seam of Jurassic Yan'an Formation, the average thickness is 5.29m, being thick coal seam, having good coal property, stable distribution, simple structure, and mainly distributed in Zhaopo syncline axis and climbs. There is no large obviously fault in coalfield, also fracture undeveloped. Coal seam and its surrounding rocks are complete, and the underwater flows slowly. The 4# coal geological reserves are 8009.0Mt, of which the basic geological reserves (111b+122b) are 4682.0Mt, taking up 58.46% in the whole reserves. During the exploration, 13 samples of the 4# coal gas are collected, including 11 samples of coal gas and 2 samples of main coal roofs (surrounding rocks), of which the CH4’s maximum value is 48.49%, and the maximum content is 3.13 m³/t, and the gas contents in top layer and in coal seams is basically the same. During the tunnel excavation and trying production periods, the coal gas value is over limited sometimes in the ZF1404 working face. This paper aims to summarize many completely measures dealing with coal gas based on analyzing the factors those geological conditions affecting mine gas.

Fig. 1. The structure and coalfield location map of Bin-chang mining area

2. Characteristics of geological methane Occurrence

2.1. Trap effects of coal seam roof and floor rocks

The gas must be trapped and reserved during its development or after the development to form gas reservoir, which is up to the displacement pressure of mechanical properties. When the displacement pressure reaches higher than the reservoir pressure, gas can be reserved in the coal seam and can not be lost. For the 4th coal seam, there are more mudstone, siltstone and sandstone in the roof and floor, and in extreme cases there are also limestones. The general case of mudstone, siltstone is relatively dense, pore radius, higher displacement pressure; the gas has a strong storage capacity [1-3]. The 4th coal seam roof in Jiangjiahe are mudstone and carbonaceous mudstone, the thickness is 12~20m, and seam floor are the
brown-gray mudstone, bauxitic mudstone and carbonaceous mudstone, thinking about 4~10m. The roof and floor layers have low porosity, low permeability, high displacement pressure, so play a barrier properties role in the gas, and have a very good preservation effect on the gas.

2.2. Effects of fold structure on gas occurrence

Fold structure belongs to the elastic-plastic deformation and can be reserved for a range of original stress status. In the folds of the axis position, relative high pressure is formed and becomes the good parts of gas occurrence [4-5], just to the syncline structure, the dip angle of its climbs is small, fractures undeveloped or develop reverse fault, so all these are advantageous to the gas preservation [6]. Jiangjiahe mine, located in the Bin County anticline to the south and Taiyu anticline to the north, depicted in Fig.1, the coalfield range is mainly controlled by Zhao Po syncline, the synclinal two limbs dip are gentle and the faults are undeveloped, at the same depth and under the same conditions, which is conducive to gas concentration. Therefore in middle of minefield the N2-CH4 belts are formed and some local sections CH4 belts are formed [7].

2.3. Effects of geological evolution on gas occurrence

Jiangjiahe mine is located in the south of Bin-chang mining area in Erdos basin and it has inherited the features of the Carboniferous, Permian, Triassic sedimentary basin. Since the Mesozoic and Cenozoic, the surrounding of the basin is influenced by Yanshan and Himalayan tectonic movement [8], within the basin, Bin-chang mining area is not reformed by large tectonic movements and large fracture zone and fault cannot be found [7, 9], leading to the gas in the Mesozoic Jurassic coal seam of Yan’an Formation not being released effectively and absorbed in coal body, so provide advantage conditions for gas enrichment.

2.4. Effects of maceral on gas content

From coal petrology, coal is made up of organic macerals and minerals. The high mineral content is disadvantageous to the gas reservoir, making the coal adsorption capacity and air content reduce [10].

Table 1. Micro-maceral sum up list of 4# coal

<table>
<thead>
<tr>
<th>Maceral Count</th>
<th>Organic Constituent (%)</th>
<th>Inorganic Constituent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vitrinite</td>
<td>Half Vitrinite</td>
</tr>
<tr>
<td>Minimum</td>
<td>13.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Maximum</td>
<td>30.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Average</td>
<td>2.11</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Jiangjiahe coalfield exploration data are listed in Table 1. The organic maceral content is higher than macerals of the 4# coal, the average value is 94.3%, in which vitrinite and half vitrinite content is relatively low, the average is 25.3% and the inertinite average is 66%, exinite content is less and average value is 3%, showing vitrinite> inertinite and vitrinite> exinite . The average value of inorganic content is 5.7%, of which the main elements are clay and carbonates, sulfides content is less, in addition, the
inertinite and vitrinite content is higher, which is advantageous to the gas adsorption and increase content [1,11].

2.5. Effects of coal metamorphic degree on gas content

As the reflectance of vitrinite is about 0.6%~1.3%, it is between first and second coalification discontinuity change, the content of carbon increase, original coal pore (>30nm) reduces, secondary pore (<1.3nm) increases, coal ratio surface area increases accordingly, molecular arrangement are in rules, unit area of carbon atoms in the density increases, the polar group reduces, the adsorption of water component is greatly reduced, so the coal adsorption capacity is increasing rapidly [1]. The 4# coal seam in Jiangjiahe mine belongs to low metamorphic bituminous coal[7,11], vitrinite reflectance is 0.593~0.648%, the average value of the carbon content is 82.85 ~ 83.20% and the formed depth is less than 149m [12], which indicate the 4# seam maturity is not high, gas potential is large, coal ratio surface area increases, gas absorption capacity increases, and after mining activities, gas desorption and migration become easy[4]. It is an important factor that coal seams mining coal coalface gas increases after disturbance.

2.6. Relationship between gas content and groundwater activity

The groundwater activity condition decides gas migration and enrichment, the groundwater detained area is the migration destination, is also the end place that the gas migrated [1, 10]. In Jiangjiahe's coal mine the 4# coal seam saturated water is low, and between Yijun fm, Luohe fm, Zhiluo fm aquifer and coal seam, there is mudstone which has poor permeability. The coal seam floor is bauxitic mudstone and variegation sand-mudstone which have already separated water function as well and the thickest place can reach to 30m or more, therefore the groundwater flows slowly, making the gas moves disposal and lack active power. So That the gas doesn't disposal with the underground water’s moving, on the contrary, it enriches in the rich underground water area, namely synclinal axis section and two climbs depicted in Fig.1. In addition, the groundwater of Yijun fm, Luohe fm and Zhiluo fm aquifer are mainly phreatic water and confined groundwater, which have a good storage effect on gas.

2.7. Relationship between gas content and buried depth

The methane zone is under the coal seam gas weathered zone, buried depth of coal seam and gas content exist a positive relation, that is, as the coal burial depth increases, the gas content increases [4, 13]. In the same natural conditions (such as moisture, temperature), the gas content equaling to methane pressure is 0.15~0.20Mpa; bond coal is 2~2.5m³/t [14]. The ZF1404 coalface is at an altitude +648.1~+573.3m, and ground is at an altitude +1002.6~+1219.8m, but the overburden effective thickness is about the 354.5~646.5m, the highest content of gas is about 3.13m³/t, in the 4# coal seam gas weathering zone, as the depth increases 85.50m, the gas content increases to 1.0m³/t. Therefore, gas content has the tendency to increase with the buried depth increasing.

3. The Features of gas emission

The ZF1404 coalface is towards the NE, the working area is in Zhaopo syncline core part, which crosses the syncline gas enrichment area, it is under trial production in July, 2010, using the long wall fully mechanized top coal caving mining method, the height of coal mining is 3.0m, the average height of caving is 4.0m, mining ratio is 1:1.3, adopt all caving method manage roof. The planned air volume of working area is 1700m³/min and the actual quantity is 1900m³/min. The coal mining depth in the initial
mining 100m range is about 1.5~3.0m, rock cutting thickness is 0.1~1.5m, gas emission quantity is 11.4m³/min and gas mainly comes from coal wall, roof rock and coal. Mined to 120m, top coal thickness is increasing gradually and beginning to use fully. During mechanized sublevel caving, so gas in great quantities close to the layer flows out and rushes into the empty area, and also gushes out of the working place. The gas emission quantity is up to 28.5 m³/min or so, and the last corner cape gas density is usually out of limitation, which threatens safe production seriously, so under the gas influence, at ZF1404 coalface, common production can’t continue and have to stop producing a 20~30 min or so, and after gas density returned to normal, the production can be continued. Aiming at the characteristics that gas in great quantities rushes at the coalface; several managing steps are taken in the ZF1404 coalface in Jiangjiahe coal mine to ensure the work safety of mining.

4. Preventing control measures on gas

4.1. Arrangement of air brattice

The main principle of gas management in corner cape of coalface is forming a turbulent zone, making gas and air dilute mixed, by hanging the air brattices to make a part of air flow through the upper corner, gas at the upper corner is diluted and discharged to avoid gas accumulation caused by airflow being not free at the upper corner and reduce gas density and prevent gas transfinite effectively [15, 16]. There air brattices are arranged at the ZF1404 coalface, including two windshield curtains and a guide air curtain, which controls the direction of wind flowing, so this is good to gas dilution at corner and preventing gas accumulation, and also the air curtains move ahead as the coalface moves, shown in Fig.2.

![Fig. 2. The gas drainage map of up corner](image)

4.2. Arrangement of high pressure wind pipe

When coalface upper corner of airflow can not effectively drain away part of gas accumulation at upper corner, can set up high pressure wind pipe, using high pressure air to blow away the gas accumulated partly at upper corner. So it speeds up the rate of the fresh air and gas mixture, and improves the efficiency of flow dilution gas and prevents local gas density being too high. At ZF1404 coalface, gas
at the end of 100th support and 99th support tail often over limited, which seriously affects the safety of production, in order to prevent the gas gauge, a high pressure wind pipe can be set up between the tails of the two frames and it can be opened when cutting coal or moving frame to break up the gas accumulated, and effectively prevent the local gas accumulation depicted in Fig.2.

4.3. Increase air volume in coalface

Coal seam distribution in ZF1404 coalface is controlled by the syncline, the thickness in the middle of coal seam coalface is about 9.5~11.0m and the coal seam thickness at both ends is about 1.5~1.8m. Gas occurrence is affected by syncline structure and in the central seam thick zone, gas occurrence is in large quantity, so in the mining process, gas emission is significantly increased. And the original designed air volume is 1700m$^3$/min, which cannot meet the requirements of production, so according to the actual situation, the air supply volume is adjusted to 1900m$^3$/min.

4.4. Drainage gas of neighbor coalface gob

The ZF1402 coalface is next to ZF1404 coalface, where production test has been carried out, there are large quantities gas accumulated in gob, which seriously affects the ZF1404 coalface production and larger potential safety hazard exists. ZF1402 coalface gob is next to ZF1404 coalface, and the rigid drainage pipes are buried by coal pillar, which drain gas of neighbor coalface gob and effectively prevent the adjacent coalface gas along the surface of coal pillar fractured migration to ZF1404 coalface upper corner, resulting in high concentrations, so that it affects the coalface production shown in Fig.3.

![Fig. 3. The gob gas drainage map of neighbor coalface](image)

4.5. High level drilling field drainage coal seam and gas in wall rock in advance

According to the analysis of Jiangjiahe coal mine geological exploration report, the gas of the 4th coal seam is not only self-generating and self-preserving, but also has a lot of gas reservoir in surrounding rocks, whose contents are equal to each other, depicted in Table 2. Mine gas comprehensive drainage technology was applied successfully in Bin-chang mining area in 2005 and had achieved good results [17]. High level boreholes drainage adjacent layer gas technology (drilling field in coal seam roof) is aimed at
high content gas without coal pillar (no tail roadway), and the characteristics of fully mechanized mining, or comprehensive mechanized coal mining technology. In order to solve the gas over limited problem, arrange the directional horizontal long borehole along the mining layer to replace the roof gas drainage channel of the next to layer or gas in gob [16, 18]. According to the coal occurrence and mining condition in Jiangjiahe coal mine, adopting high level boreholes to drainage adjacent layer gas, which can drainage self seam gas, and can truncate gas of neighbor layer, which effectively solves the issues of the 4# coal seam and the upper corner gas greatly emission shown in Fig.4.

Table 2. The firedamp testing check list of 4# coal and the roof layer

<table>
<thead>
<tr>
<th>Drilling No.</th>
<th>Seam No.</th>
<th>CH(_4) (%)</th>
<th>CO(_2) (%)</th>
<th>N(_2) (%)</th>
<th>CH(_4)ml/g daf</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-2</td>
<td>Top layer of 4# Seám</td>
<td>35.64</td>
<td>1.91</td>
<td>62.45</td>
<td>1.99</td>
</tr>
<tr>
<td></td>
<td>4# Seám</td>
<td>40.35</td>
<td>3.12</td>
<td>56.53</td>
<td>2.39</td>
</tr>
<tr>
<td>3-1</td>
<td>Top layer of 4# Seám</td>
<td>31.46</td>
<td>2.99</td>
<td>65.55</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td>4# Seám</td>
<td>28.30</td>
<td>2.20</td>
<td>69.50</td>
<td>2.41</td>
</tr>
</tbody>
</table>

![Fig. 4. The high position drilling yard gas drainage map of neighbor layer](image_url)

4.6. Gas drainage in mining coal seam

The coal seam internal cross borehole drainage is used in ZF1404 coalface in coalface tailgate side, the layer cross borehole mining before the coal seam gas pre-drainage is applied, and mining pressure relief gas drainage is used with coal mined. Horizontal drilling borehole spacing is 10m and the length is 95m; oblique borehole spacing is 10m and the length is 110m; horizontal borehole and oblique borehole are intervals, and the borehole spacing is 5m. 160 horizontal boreholes and the 160 oblique borehole are set up at coalface, single borehole average drainage quantity is 0.025m\(^3\)/min or so and mining coalface drainage quantity is 8m\(^3\)/min or so that depicted in Fig.5.
4.7. Gas drainage in mining coal seam

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![Gas drainage sketch map of mining coal seam](image)

Fig. 5. The gas drainage sketch map of mining coal seam

5. Management effects

a. Guiding wind curtains and high pressure wind pipe are arranged in coalface upper corner, and setting up pipe to drainage gas in the gob of neighbor coalface. All these have good effects on controlling gas, and the times and periods of gas over limited decrease significantly.

b. Increasing air volume in the coalface, accelerating the gas discharge rate, reduced the gas concentration significantly, which is in coalface and return airflow roadway, plays a dominant role in gas management in the coalface.

c. In ZF1404 coalface, mining coal seam gas drainage quantity is about 8.0m$^3$/min, gas drainage quantity is 3.5m$^3$/min in the gob and adjacent layer, so mine gas drainage quantity is about 11.5m$^3$/min, total emission of mine gas is about 26.97m$^3$/min[18], and drainage rate is 42.2%.

6. Conclusion

a. In Jiangjiahe coal mine the 4" coal seam is affected on a structure, covered by roof and floor mudstone, buried in greatly depth, structure is simple, coal seam dip angle is gentle, groundwater flows slowly, coal metamorphic degree is in low rank, and maceral of inertinite and vitrinite content is higher and other factors, the results which are that gas content is higher in the coal body, that gas enrichment
zone is formed in Zhaopo synclinal axis section and climbs, revealed gas enrichment of geological factors, also points out the effective parts for gas control.

b. According to the characteristics of gas distribution, during mining in the middle of coalface, as the gas emission is gradually increasing, air brattice and high pressure wind pipe are set up, and gas in adjacent coalface is pumped drain system is set up, and increase the air volume supply, construct high level drilling field drain the gas in the neighbor layer and gob, drain the mining coal seam gas, and other comprehensive control measures manage gas emission in the ZF1404 coalface achieved good results, so provide advantageous safeguard for the safety production of coalfield.

References