Gas Extraction Techniques Based on Gas Geology in Zhengzhou Mining Area

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Abstract

The article analyses gas geological characteristics in Zhengzhou mining area from structure, buried depth, coal thickness and several other factors, especially sliding structure, they have not only controlled coal seam genesis and tectonic coal distribution, made coal seam gas further release and could confine coal seam gas, but also made gas pressure critical value of coal and gas outburst lower, then analyses signs and regularities of gas outburst in the area, and targeted to research on gas extraction techniques, finally, proposed gas control countermeasures, and has effectively promoted safe development in the area.

Keywords: structure; coal gas geology; gas extraction techniques; Zhengzhou Mining Area

1. Introduction

The western Henan coalfield contains Xinmi coalfield, Dengfeng coalfield, Xinggong coalfield, Yanlong coalfield, Xin’an coalfield, Yiluo coal, Shannian coalfield, Yuzhou coalfield, etc. These coalfields have similar gas-geological conditions. The coal seam has gas outburst’s hazard, the coal and...
gas outburst has occurred. Zhengzhou coal mining area includes Xinmi coalfield, Dengfeng coalfield, Xinggong coalfield, Yanlong coalfield. Zhengzhou Coal Industry (Group) Co., Ltd-owned coal mines are mostly concentrated in the first three coalfield. Zhengzhou coal mining area is a demonstration area for coal and gas prevention defined by the Ministry of Science and Technology and the State Administration of Work Safety Supervision during the "Eleventh Five-Year Plan". Zhengzhou Coal Industry (Group) Co., Ltd, cooperating with Henan Polytechnic University, China University of Mining and Technology and other research institutes, has achieved staged scientific achievements.

2. Features of gas-geology

2.1. Influence of structure, depth and coal thickness on gas occurrence

2.1.1. Control of structure to coal and gas

(1) Fold and fault

Xinmi coalfield is located in the northern margin hinterland thrust fold belt of the Qinling, NNE - NE structure superposition binding sites control the area of complex structure and the dangerous zone of coal and gas outburst [1][2], such as in Taiping mine, Gaocheng mine and Chaohua mine. These dangerous zones of coal and gas outburst are located in the coalfield of NNW and NNE structure superposition. NNE-NE trending Ying Yang - Ludian syncline is the NW-NWW composite structure. These gas occurrence conditions of coal seam are good, tectonic compression deformation has been intense and tectonic coal has been developed. Gaocheng mine is located in the south of the syncline.

The main faults in this area are the extensional normal faults, such as Shayugou, Wuzhiling, Xuedian and so on. These boundary faults form the boundary of dissipation of gas in coal seam 21. The distribution of gas geological units is controlled by aforementioned structure. The same as sliding structure, the fault development is not only favorable to direct diffusion of gas, the rocks in two blocks of the fault have been also destroyed in different degree, which is favorable to groundwater activity, groundwater circulation dissolved and carried gas, finally made the gas diffuse, water molecules occupied micro-pores space of coal, not only pushing out free gas, but also reducing the adsorption capacity of coal pores, so the gas content of seam is decreased. For example, in dry coal gas content was high, but in wet coal gas content was low during mining coal seam 21.

(2) Sliding structure

a. Origin of structure- controlled coal seam and distribution of deformed coal

The main structure is NW-NWW in strike in Xinmi coalfield and superimposed by NNE - NE structure. Massive fault activity occurred during Mesozoic Late Jurassic - Early Cretaceous and Cenozoic Tertiary, such as Songshan, Wuzhiling fracture and others were reversed into normal faults. Especially in the Late Cretaceous to Early Tertiary, the NNE tectonic stress field was reversed, the extension fault activity emerged, the Yuewan fault and Shizonghe fault reversed into normal faults, inducing famous gravity sliding structure in western Henan[3]. This made the coal seam widely sheared and slid, the coal thickness changed drastically from 1 m to tens of meters, deformed coal developed into layers. This is the main reason for "three soft" coal development in Xinmi coalfield [4].

b. The gas was further released and confined by sliding structure

Sliding structure is upward or downward sliding of coal and weak rock by gravity during the descending of the upper block of normal faults in the stretching background. Sliding structure made gas release further, especially in a coalfield controlled by upward sliding structure. Because of tectonic tilting, formation slipped and tilted, coal seams were shallowly buried. This controls the distribution of low-gas mine mainly represented by mines where NW-NWW normal faults were predominant, for example, Wanggou mine, Wangzhuang mine, Micun mine, Lugou mine, Zhanggou mine and others are all
low-gas mines. But, if there is thick tough rock in coal seam roof, dense, smooth, gas/water–isolating lubricating layer occurred near the sliding face during formation of sliding structure, which prevented gas from moving to the roof and confined gas, such as Dayugou sliding structure, Xuzhuang sliding structure, the Sanli sliding structure and others which developed from west to east in Xinggong coalfield, for example, Cuimiao mine and others are outburst-prone mines. 

**e. Coal and gas outburst pressure is low threshold in "three soft" coal seam in Xinmi coalfield**

Under action of sliding structures, "three soft" coal seams in Xinmi coalfield have been destroyed intensively, IV, V deformed coal was developed into layer, the f value of coal was 0.35 or less, and some about 0.1. the gas pressure of 10 of the 11 coal and gas outbursts was below 0.64MPa in Taiping coal mine; the gas pressure was only 0.57 during an outburst near 21021 lane in Gaocheng mine; the gas pressure was only 0.5MPa when three outburst occurred near the 22121 lane in Chaohua mine. Therefore, the gas pressure threshold may be less than 0.74MPa in Xinmi coalfield. The high-gas outburst coal mine and low-gas coal mine are distributed from north to west by strip in Xinmi coalfield. Coal mines are mostly highly gas-prone in the south, those in the north are of low gas.

**2.1.2. Buried Depth**

The gas content, emission and pressure in coal seam increase with depth regularly below the weathered zone. The reason: with increase of coal depth, firstly, coal rank increases, gas generation and adsorption capacity were strengthened; secondly, the overlying strata were thickened, the path for gas migration increased, the confining conditions became better, which was favorable to preservation of great amount of gas; thirdly, the ground pressure increased, the adsorption capacity of coal increased too, prompting more free gas into absorbed gas, so a lot of gas remained. But to certain depth, coal density increased, porosity decreased, gas permeability also decreased, and the growth rate of gas content decreased and was gradually stabilized. Gas content increased rapidly under 300 ~ 600m depth, then gradually slowed down to 800 ~ 1000m deep and was stabilized to reach the limit. In coalfield, although the gas distribution is extremely uneven, affected by many factors, the depth as one of the most important trend factors is still obvious.

**2.1.3. Coal thickness**

The coal seam 21 is thick. In general, gas content is large in thick seams, the gas content is relatively little in thin seam of poor quality [6]. Coal gas is generally enriched in thick coal seams; coal package is also often gas package. Judging from the production wells, the gas emission also increases with coal seam thickness. In this area the thickness of coal seam 21 changes greatly (0 ~ 23.80m), which is an important reason for the uneven distribution of gas. Gas in the coal seam 21 is not only large, but also the seam is prone to outburst. It was confirmed by production and outbursts in mines that the variation of seam thickness destroyed the equilibrium of gas in seams, contributing to gas migration and change [7].

**2.2. Symptom of coal and gas outburst**

In general, the form of symptom of outburst is ring gun, crown drill, clamp drill, suction drill. In a few cases, it is nozzle, coal plane upheaval and so on. The symptom of coal and gas outburst located in gas zone of middle geological units, but symptom is not obvious in gas weathering zone, showing the control of gas zone on outburst. The symptom of coal and gas outburst is generally situated in place where the thickness of coal seam changed sharply. Usually, the sharp change of seam dip was induced by fold and variation of seam thickness as well fault. The symptom of coal and gas outburst was generally located in a zone of thick and extreme thick coal seam. The symptom of coal and gas outburst is not obvious in the zone of medium-thick seam and thin coal seam. It shows that the thickness of coal seam controls the coal gas outburst.
2.3. The rule of coal and gas outburst

2.3.1. The beginning of conflict of depth and elevation

In Daping mine the depth of outburst was shallow, the initial outbursting depth can be set at 250 m, in Gaocheng mine, Chaohua mine and Peigou mine, the depth of outburst was relatively big, the initial outbursting depth can be set at 350 m, 400 m and 398 m. The initial outbursting depth in different mines was characterized by wavy relief. Compared with the Daping mine, the special gas geological conditions in Gaocheng mine were developed sliding structure in seam roof through the mine, those in Chaohua mine particularly developed faulting structures. Both sliding structures and faulting structures were favorable to gas diffusion, the depth for gas content to reach the threshold was greater. From the elevation of outburst, the initial outbursting depth in different mine and the same mine was greatly different and there was no regularity. Of these mines, the elevation of outbursts has the biggest difference in Daping mine, where the initial depth of outbursts did not have significance. In Gaocheng mine the elevation of outburst can be set at -50 m, in Chaohua mine and Peigou mine, the elevation of outbursts can be set at -200 m and -186 m. The elevation difference was mainly controlled by topography.

2.3.2. Location of outburst

Of 40 outbursts, 3 large-scale and ultra large-scale outbursts occurred during uncovering coal in roadway and crosscut, or isolated heading excavation, taking about 7.5% of the total, other 37 outbursts took place during heading excavation of extrusion, pouring or caving, taking about 92.5%. What must be emphasized is that three large and ultra large-scale outbursts all took in uncovering coal in crosscut or isolated heading excavation. The position of outbursts is at the deepest part of mine. Comparing with small-scale gas outburst, the gas content is only higher 0~2 m³/t. It can be seen that uncovering coal in crosscut and isolated heading excavation was the key factor of gas outburst when gas content was at critical value.

2.3.3. Outburst intensity

Of 40 gas outbursts, 1 was of ultra large-scale, 1894t of coal were burst [8]; 3 were of large-scale with burst coal of 118t, 948t and 401.2t respectively; 1 was of medium-scale with burst coal of 70t; others were of small-scale with burst coal of 25.13t in average. The distribution of outburst intensity had regularities, in Gaocheng mine the intensity of caving was higher than that in Daping mine.

2.3.4. Outburst types

According to outburst characteristics, of 40 outbursts, 3 could be classified into outbursts, accounting for 7.5%; 22 were pressing and pouring, taking about 55%; 15 were abnormal gas inflow caused by caving, accounting for 37.5%. Before 2004 the gas outbursts were mainly small pressing and pouring, after 2004 3 outbursts of large to ultra large-scale occurred, indicating that with the increase of mining depth the risk of gas outburst has also increased.

3. Gas extracting technology

By analyses and studies on the regional gas geological features, coal and gas outburst signs and regularities, based on the latest "provisions of coal and gas outburst prevention", the following gas extracting technology has been adopted in different coal mines, and it can lower the gas content and gas pressure in coal seam, and ensure safety in production.

3.1. Boreholes along seam firstly are used for control then are put denser driving

In the dangerous area of coal and gas outburst, the strip gas pre-drainage by drill hole through strata has been conducted, after verification of effective regional measures, coal seams driving was in
outburst-eliminated area. During coal roadway driving, 9 in-advance exploration boreholes (Φ=89mm, L≥60m) were drilled to identify the situation of coal seam gas. If the drilling process became abnormal, the dense extracting boreholes were drilled in front of mining roadway. The outburst forecast index (q·S) must be lower than the critical values, and the driving work can be done.

![Diagram](image1.png)

Fig. 1. The layout of drainage and drilling in the heading face

### 3.2. Regional outburst eliminating measures to improve permeability and relieve pressure

Before driving in the dangerous area of coal and gas outburst, a special roadway was excavated for gas extraction in roof/floor of seam, and the length of the roadway can basically cover the whole dangerous area of outburst. In the special roadway for gas extraction, at every 40 m a drill site for gas drainage was set to drill gas drainage boreholes to control the driving area of coal roadway. The drainage boreholes were arranged in grid, the length was 30-60m, the interval of borehole endpoint was about 10m. The gas drainage borehole drilling site consisted of 24-32 boreholes. When drilled to predetermined depth, the boreholes were hydraulically flushed by high pressure water. The coal flushed-out coal volume in each borehole could be more than the 5% of controlled coal. After the hydraulic flushing, the concentration of drained gas was 10%-20%, the negative pressure of drainage was 13-18KPa, and the pure gas drainage flow was 0.5-0.8m³/min.

![Diagram](image2.png)

Fig. 2. The layout of the bottom (roof) rock of drainage roadway
3.3. Along seam gas drainage boreholes to eliminate gas outburst

Before working face was mined, the drainage boreholes along seam with parallel arrangement were drilled in intake alley and return airway of working face, and the borehole interval was 2.5-3.5 m, 1-3 drilling layers were set depending on coal seam thickness to ensure that the borehole were evenly distributed in strike and dip of coal in coal extraction area. Due to the limitation of powder discharge of downward boreholes in upper subsidiary roadway, it is difficult to drill boreholes, the length of downward-hole was 30-50m. The upward-holes were easy to drill, and their length of 60-80m was economically reasonable under air pressure of more than 0.8MPa. Along seam boreholes pre-drain gas of the seam before extraction of working face, and the pre-drainage time was about 3-6 months, they continue to drain gas in coal seam during coal extraction.

3.4. Combination of boreholes in ear lane with boreholes in with heading

7-10 boreholes were drilled in the front of heading face, and the diameter was more than 89mm, the depth was 30-50m, the controlled area of boreholes region of drilling exceed the roadway outline by >3m. The drill site was set at the two sides of roadway, and 4-5m deep, the interval between two drill sites was about 50m, at least 4 gas drainage boreholes were set in each drill site, and the diameter was more than 75mm, the control scope of two sides of driving roadway was more than 15m.

Fig. 3. The layout of parallel gas drainage boreholes in working face

3.5. Special gas extraction roadway in roof

High roadway which paralleled the return airway tunnel was dug in the coal seam roof, and the gas in the gob from near coal bed was drainage. The high roadway was assigned along the coal seam, and is 30m from the inside of return airway tunnel. This method can drainage the gas which came from gob when the rock and thick coal seam dug, it can successfully reduce the working face upper corner gas emission and guarantee safety in production.

Fig. 4. The layout of frontal drilling in lane in the heading face
High-level roadway paralleled to the return airway was excavated in the coal seam roof of coal face, and the gas in the gob from adjacent coal seam was drained. The high level roadway was located along the top of seam 2, and 20m away from the inside side of the return airway. This method could drain a lot of gas flowed into the gob when mining thick seam 2 and caving of surrounding rocks, it could successfully reduce gas emission in the upper corner of the working face and guarantee safety in production.

![Fig. 5. The layout of roof drainage roadway in the working face](image1)

**3.6. Gas drainage by high level boreholes**

Before working face was mined, a high level drill site was set every 60 m in return airway, in which 8-10 boreholes were drilled in form of fan. The boreholes were located in the fractured zone of 20-30 m above the working face and 60-80 m long. This measure was used mainly to prevent gas from surpassing the limit in the upper corner, finally to realize fully safe and efficient production of working face.

![Fig. 6. The layout of high level borehole in the working face](image2)

**3.7. Drainage by buried pipe in gob**

A straight tee was installed 10-15 m away from the external port of the upper roadway of working face, with two branch pipes equipped with valve, when the embedded spiral pipes entered into the gob area about 30 ~ 50m, the control valve was opened to drain gas in gob, in the same time another spiral tube was laid. When buried tube drained at scalar quantities (into the gob about 50 ~ 60m), the valve was closed and pipe later laid was opened to drain gas in the gob. Pipes were buried by circular steps. Totally
25,337,000 m³ of gas were extracted in 2010, completing well the plan.

Fig. 7. The layout of drainage by buried pipe in gob

3.8. The inclined boreholes in upper subsidiary roadway of working face

Before mining the face, a drill site was set at intervals of 50m in haulage roadway. From the drill site, a set of 8-10 boreholes were drilled to the gob behind the working face. The horizontal angle of boreholes was 30° ~ 60° with the upper subsidiary roadway and terminated at the top of fractures above the roof fall of working face. They were mainly used to drain gas in gob and to prevent gas in the upper corner from surpassing the limit. The boreholes were 60 ~ 80 m long, they can effectively block the upward emission of gas in fractures when the thick coal seams are mined.

Fig. 8. The inclined borehole in working face

4. The gas control measures and conclusion

4.1. Compilation of gas geological maps of mining areas, mines and mining district, integration of gas geology data, summing up regularity of gas geology will play important role in guiding prediction of gas and coal outburst risk, comprehensive control of gas and ensuring safe production in coal mines.

4.2. The rate of the gas extraction was more than 30%, the residual gas content in coal decreased to less than 6.5 m³/t, the highest gas concentration was 0.8%, this technology has eliminated risk of coal and gas outburst in working face, coal mining by caving has been adopted, resulting in significant economic benefits.

4.3. Attention should be paid to compilation of gas geological maps, the principle of priority for gas drainage should be upheld, gas drainage must be deepened, execution of regional outburst prevention
measures must be reinforced, engineering volume of gas control must be ensured, and implement to ensure that the amount of gas prevention and control projects, the concept of simultaneous extraction of coal and gas must be deepened, active prevention and green mining must be conducted.

References