Research on Prevention and mitigation of Deep Mine Hazards in Ningzheng Mining Area

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Abstract: Ningzheng Mining Area, as one of the key mining areas of Longdong Energy Base in Gansu Province, whose average overburden depth of coal seams is more than 800 meters and average thickness of coal seams ranges from 8m to 14m. This paper analyzed the typical characteristics of water damage, heat damage, high mine pressure and gas disaster in Ningzheng mining area. Disaster prevention measures and two resource utilization prevention technologies (namely EMS cooling technology, Gas power generation and cogeneration system cooling technology) were put forward, the research has a realistic significance for the safety exploitation, comprehensive utilization of deep coal resources in China, energy conservation and emission reduction and development of circular economy.

1. Introduction

Ningzheng Mining Area is one of the key mining areas of Longdong Energy Base in Gansu Province. It is the main development area for future coal supplies in Gansu Province. Ningzheng Mining Area has 8.7 billion tons of recoverable coal reserves. The total coal production is 39 million tons/year, mainly including Hetaoyu, Xinzhuang, Jiulongchuan and other mines. Hetaoyu and Xinzhuang are under development with a planning production of 800 million tons per year each. It is expected that the Hetaoyu mine will be full production by 2019. Jiulongchuan will see a reduction in production due to the decreasing coal demands. The Ningzheng Mining Area is located in the southern margin of the Ordos Basin. It is mainly the Jurassic Yan'an Formation coal system. The overburden depth of the coal seam is more than 800 meters. The main geological structure is relatively simple with the Northern Shaanxi slope and the Western Tianxiang syncline. The stratum was slightly modified by the later geological movements, forming a thick coal seam with an average thickness of 8-14m. The main coal seam in the area is located under a confined water body of the Luohe Formation, which will threaten the safety of coal mining in this area. Ningzheng Mining Area is facing very challenging mining conditions associated with water hazard, heat stress, high ground pressure etc^[1].

2. Analysis on typical hazard characteristics

2.1 Analysis on water damage characteristics

As shown in Fig.1, the mining area consists of five aquifers. The first top aquifer is Quaternary Holocene

grit layer pore aquifer; the second aquifer is the Lower Cretaceous Zhidan Group, which is mainly composed of decial fine sandstone, a porous aquifer with pores and fractures, with a thickness of about 200 meters. The third aquifer is Lower Cretaceous Zhidan Group Luohe Formation, and mainly composed of coarse sandstone. The pores and fissures are confined to aquifers with a thickness of about 440 m. The fourth aquifer is the Middle Jurassic Zhiluo Formation, the upper and middle sections of the Yan'an Formation (above the coal 8th floor), and the lithology is dominated by siltstone. The thickness is 110m, which is a confined aquifer; the fifth aquifer is the Lower Triassic sandstone, conglomerate pore and fracture composite aquifer in the lower part of the Middle Jurassic Yan'an Formation

The first and second aquifers are buried shallowly, and are relatively far from the deep main coal seam. Therefore, when the coal seam is mined, the water-conducting fracture zone does not extend beyond the surface and the Quaternary bottom boundary. These two aquifers have insignificant effect to the mining coal seam. The most significant influences come from the third aquifer which is the Lower Cretaceous Zhidan Group Luohe Formation. The aquifer is a confined aquifer located above the roof of the coal seam. The water-conducting fissure zone formed after the mining of the 8th layer of coal is highly accessible and the height of the fissure zone reaches up to 160 meters. The bottom of the aquifer of the Cretaceous Luohe Formation is only about 110 meters away from the 8th layer of coal, which will cause the pressurized water of the Luohe Formation to enter the mine via the fracture zone and become the direct aquifer of the mine. The fourth and fifth composite confined aquifers also have a certain impact on mine mining. In addition, some joints, large fissures and small faults are developed in the water-cracking zone, and the Huachi and Luohe Formations are loose, rich in muddy

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loose materials, staggered bedding development, poor cementation, and easy to collapse. In the shaft excavation, the unloading effect will widen the cracks, enlarge the water permeability, and form water guiding channel, which will significantly enhance the water guiding capacity. In some local fissure with good water content, the water inflow will suddenly change due to the pressure release. The amount of water in the shaft will increase with the increase of the depth of the excavation process, which will have a greater impact on the safe production of the shaft.

Fig.1 Comprehensive column chart of main aquifer characteristics in Ningzheng mining area

2.2 Analysis on thermal hazard

According to temperature measurement data of coal 8 layer floor from exploration borehole of the Xin Zhuang, coal mines currently planned by Ningzheng Mining Area, the ground thermal characteristics are as follows:

The temperature measured at the bottom of a 1270 m deep borehole of Xin Zhuang Mine, is 40.6°C. The bottom temperature at a 758m deep borehole is 39.5 °C. The highest temperature of 46.8 °C was measured at a 1261m deep borehole. The average temperature at the floor of the coal seam 8 ranges from 31.9 to 45.5°C which fall into the categories of first-grade (31°C-36.9 °C) and second-grade (>37°C) heat hazard zones. Two-thirds of the boreholes where the temperatures exceed 37°C are in the second-grade heat damage zone and mainly locate in the southwest and west of the well field. The geothermal gradient is about 3.0°C/100m. No abnormal heat hazard phenomenon has been observed.

From the above analysis, the overburden depth of the coal seam is the main impacting factor of the ground temperature. The typical geological structure also affects the distribution of the ground temperature. The geothermal temperature along the anticline is slightly lower, and the geothermal temperature is at the oblique axis (the depression) relatively larger. The distribution direction of the thermal hazard area is related to the structural trend. The high temperature heat hazard has become an unavoidable problem in the development of coal fields in Ningzheng Mining Area.

2.3 Analysis on hidden dangers of rock burst

The mining depth in Ningzheng Minefield is around 660~1270m. The large overburden depth will likely cause coal or rock burst due to high ground pressure. At present, no rock burst has occurred in the mining process. But statistical analysis shows that the possibility of rock burst increases with the increase of mining depth. When the mining depth exceeds 800m, the risk of rock burst will increase dramatically.

The Ningzheng mining area is located on the Yishan single slope of the east ring of the Tianhuan syncline. The tectonic form is a monoclinic structure with a gentle slope to the northwest. The dip angle of the coal-bearing stratum is generally 5-10°. The main structure of the Xin Zhuang mining area is Dengjia anticline. In Hetaoyu mining area, there is mainly the Luojiabao anticline. According to previous studies, under the dual influence of bearing pressure anomaly and structural stress anomaly, the possibility of pressure-type impact of coal rock near the fault zone will increase. The coal seam in the pleated oblique section is the largest horizontal stress concentration area, and it is easy to accumulate a large amount of elastic energy. The mining activity in this part is easy to trigger rock bursts, so that the high elastic energy in the coal rock body is released and impacted [8]. The intensity is relatively large when the impact occurs (see Fig 2 for details).

Fig.2 Stress map of minefield syncline structure

Through analogy analysis, during the construction process of coal roadway adjacent to a certain area of Gaojiabao Mine, there have been several recorded dynamic phenomena, including head-on impact, two-deformation and floor bulging. Shortly after the Hujiahe coal mine was put into operation, it was threatened by a strong impact of ground pressure disasters. More than ten rock bump accidents have caused the interruption in mining and development for up to five months together with casualties and roadway damages. It has been identified that the main coal seam, No. 4 coal seam, has a strong ground bump tendency.

As the thickness of coal seam in Ningzheng mining area is large, top coal caving is the primary mining method applied in each mine. After a full cut using fully mechanized top coal caving mining, the supporting pressure will shift away from the rib and the stress concentration will decrease. Therefore, the possibility of rock bump decreases accordingly.

3 Analysis on severe hazards measures

The following prevention measures are proposed

according to the typical characteristics of water hazard, heat hazard, and high ground pressure in Ningzheng Mining Area.

3.1 Water hazard prevention and control

(1) During the construction and production of the mines, hydro geological observation and research should be enhanced. Hydro geological conditions should be closely monitored and the successful experience in water control in similar mining areas should be used to provide a scientific insight for water hazard prevention and control.

(2) The top plate exploration and release water must be done while starting the first working face of a newly mining, or the first working face of the new level and the new area, in the dense fracture zone or the fold structure area or the area where the goaf may produce hydraulic connection,.

(3) During the construction and production of the mines, it is necessary to pay close attention to the increase of underground water inflow caused by surface precipitation, and do a good job in flood control and drainage. It is suggested that a flood control and drainage mechanism should be established to timely contact with local meteorological and water conservancy departments to ensure the safety of mine construction and production.

3.2 Heat damage prevention

Ningzheng Mining Area is a typical deep well heat hazard mining area. At present, mine heat damage has become the sixth major disaster in coal mines. From the perspective of miners' wellbeing, high temperature must be prevented as it is extremely harmful to workers' labor efficiency, physical and mental health it

There are general cooling technology measures and mine mechanical refrigeration cooling technology for heat stress prevention. At present, the mines under construction are fully considering the general cooling measures in the early stage of mining, development, and ventilation system design such as selecting a reasonable ventilation system, avoiding the inlet air flow passing local heat source, avoiding coal flow against air flow, shortening the air flow route, retreat mining and enhancing personal protection. All mines have selected mechanical cooling, ice cooling, or water-cooling technologies, etc to reduce the risk of heat stress. Taking Xinzhuang mine as an example, underground cooling chamber is used for centralized cooling and the ice produced by the refrigeration unit using ice-cooled air-conditioning technology is sent through the pipelines to ice melting sinks. Then cold water melting from ice is sent to the air cooler of each working place in the underground to cool the air through the chilled water pump. The pipelines transporting the flake ice are installed along the auxiliary shaft. The general cooling technology of the mine needs to be planned in the early design of the mine. The air flow of the working face is limited, and it cannot be increased indefinitely. The cooling adjustment range is small. The selection of

mechanical cooling technology is determined based on the cooling capacity of the mine to meet the cooling requirements of the working face. The shortcomings of mechanical cooling technology include large capital investment, low energy efficiency, and large and complex equipments. The heat losses of most of the technical methods are large as they do not fully consider the recycling of condensation heat, geothermal heat and hot water resources.

3.3 Prevention and Control of Hidden Danger of Rock burst

Ningzheng Mining Area hasn't had any rock burst accident yet, but there is a great risk of rock burst. Therefore, the following measures must be taken to prevent rock burst:

(1) We should do a good job in identifying coal seam rock burst in the early stage. After the coal mine enters the normal production, it is necessary to evaluate the coal or rock burst tendency for the coal seam in a timely manner.

(2) Extra attention should be paid to the observation workers who have strict rock burst accidents. The integrated atmospheric monitoring system in the mines should be equipped with ground pressure sensing probes. In production, a number of prediction and prediction measures should be taken, especially in the mining of the following areas; prevention work must be done well.

(3) The blasting pressure is relieved every 10 days or so in front of the coal wall 20 to 100 meters after a new face starts. Advanced blasting pressure is relieved while working face advances to the triangle gate 80 to 100 meters in front of stopping line.

(4) Preventing and controlling the rock burst in working face by advanced vibration blasting.

In addition, the paper fully considers the comprehensive prevention and control of various disasters, and recommends two kinds of disaster resource utilization technologies that can be used for reference in Longdong coalfield development.

4 Several comprehensive utilization measures for resource utilization

4.1 HEMS cooling technology

HEMS cooling technology was proposed by Professor He Manchao of China University of Mining and Technology. It has been used in many mines including deep mines in the east and south, such as Xuzhou Sanjianhe Mine, Shandong New Grave Suncun Mine, Hunan Zhouyuanshan Mine. The average temperature is lowered by $8\sim 10^{\circ}\text{C}$ ^[3], which has the significant advantages of cooling and recycling of heat energy. The method uses the HEMS cooling system to extract the cooling capacity from the gushing water source of the underground mining face, exchanges heat with the hot air of the mining face to cool the cooling air, and then uses the mine drainage as a medium to transport

the working surface thermal energy to the well instead of bathrooms, boilers, and building and domestic water heating [2], to achieve a change.

The HEMS cooling system is composed of underground and ground parts (see figure 3 for details). The underground part is composed of pressure conversion workstation, heat exchange workstation, refrigeration workstation, and cooling workstation. The ground part is composed of regulating pool, heat exchange workstation and heat utilization workstation to realize full utilization of heat energy. The well is connected to the well through a pump station.

Fig.3 Process schematic diagram of HEMS cooling system

4.2 Gas power generation and cogeneration system cooling technology

The system combines the mine centralized cooling system, gas drainage system and waste heat utilization system. It has the characteristics of comprehensive prevention and utilization of heat damage and gas disasters, and has obvious advantages in energy saving and emission reduction, especially for newly built large modern mines. Fully consider and draw lessons.

The principle of gas power generation and cogeneration system (see Figure 4) is as follows: The mine gas drainage system transports the high-concentration gas extracted from the gas to the gas storage tank, and uses the ground pretreatment system to filter the gas in the gas storage tank. After dehydration and supercharging, it is sent to the generator set to generate electricity. The high-temperature flue gas discharged from the power generation process is used as the mine cooling heat source and used as the refrigeration unit power of the mine centralized cooling system. The electricity generated by the gas generator set can supply power to the mine mechanical cooling system, and the excess electricity can be used as underground power generation. The system can adjust the peak according to the change of electricity consumption in winter and summer. When the cooling capacity is large in summer, the waste heat of the boiler is used for refrigeration. The waste heat in winter can be partially used for refrigeration, and the rest can be used as ground heating. The system simultaneously plans mine gas

power plant or coal gangue pit power plant, which is consistent with the concept of high-grade recycling of coal resources by large coal mines, and the concept of efficient recycling [4].

Fig.4 Principle of cooling technology of gas generation and thermoelectric cold supply system

5 Conclusions

As a large-scale energy and chemical base in the western region of China, Ningzheng Mining Area has a very complex and dangerous mining condition as deep and gassy mines. The construction of mining areas should fully consider the overall planning of large-scale modern coal production bases, take consideration into the relationship between safe production and economic benefits, ecological benefits and circular economy, pay attention to the comprehensive prevention and utilization of disasters, and carry out their own styles and characteristics.

Acknowledgement

This research paper was supported by Gansu Province 2018 Annual Safety Production Research Project (GAJ00017), (GAJ00011).

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