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Strata behavior investigation for high-intensity mining in the water-rich coal seam

Ding Huande [a,c], Miao Xiexing [b], Ju Feng [b,*], Wang Xiulin [a,c], Wang Qingcang [a,c]

[a] School of Mines, China University of Mining & Technology, Xuzhou 221116, China
[b] State Key Laboratory for Geomechanics and Deep Underground Engineering, China University of Mining & Technology, Xuzhou 221116, China
[c] Huadian Coal Industry Group Co., Ltd., Beijing 100000, China

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ABSTRACT

This paper describes a specific case of mining in a water-rich coal seam in western China. Water inrushes, roof caving and other disasters induced by intensive mining operation could pose great threats to the safety of coal mines. The strata behavior during the high-intensity extraction in the water-rich coal seam is analyzed by employing the numerical simulation method and in situ monitoring. The results show that about 10 m ahead of the workface, the front abutment pressure peaks is at 34.13 MPa, while the peak of the side abutment pressure is located about 8 m away from the gateway with the value of 12.41 MPa; the height of the fracture zone, the first weighting step and the cycle weighting step are calculated to be 45, 50 and 20.8 m, respectively; pressure distribution in the workface is characterized by that the vertical pressure in the center occurs earlier and is stronger than those on both ends. Then, the results above are verified by in situ measurement, which may provide a basis for safe mining under similar conditions.

1. Introduction

At present, the focus of coal mining development in China is shifting to the west area gradually; coal reserve in the west is up to 1.0628 trillion ton, accounting for 81% of the total reserve. Meanwhile, the coal output in the west holds more than 60% of Chinese coal output [1–3]. The coal resources mainly consist of thick coal seam with superior mining conditions, which provides conveniences for the high-intensity mining in Western China [4–6]. Miao made the following definition on high-intensity exploitation: unlike conventional mining operations, high-intensity exploitation is featured with huge mining height, long face length, high advance speed and production [5–8].

The Xiaojihan Coal Mine, 12 km west of Yulin city, is the first mine with 10 million tons per year in Jurassic Coalfield. It has an area of 251.75 km^2 with geological reserves of 3.17 billion tons and recoverable reserves of 1.89 billion tons. The mine has been designed production capacity of up to 10 million tons, and the only one workface has formed a pattern of such high intensity exploitation.

The Jurassic Coalfield in northern Shanxi province, located at border region of the Maowusu desert and the Loess Plateau, is a typical desert area. It has been taken as an arid and semi-arid area for a long time. However, with continuous mining in recent years, frequent water inrush hazards have arising great concerns. As a result, many advanced technologies in regard to water-conservation mining have been proposed as a solution [9–11].

With the development of the Xiaojihan Coal Mine, the coal seam was unusually found to be a rich aquifer. Water inflow suddenly increased to 82 m^3/h and pressure soared up to 2.3 MPa when excavating the ingate. During the excavation of the 2nd western return airway, lots of water sprayed out from a fracture along the N-S direction at the heading face. The initial hydraulic pressure and the accumulated water inflow were monitored to be 2.6 MPa and 750 m^3/h, respectively. This adverse condition have seriously affected the mining operations. To ensure the safe and efficient mining, research on the strata behaviors is quite necessary.

2. Mining conditions

2.1. Coal seam

The 11203 working face mined has a dip angle of 0°–1°, with average dip of 0.7°, and thickness of it ranges from 1.6 to 2.95 m, with average thickness of 2.67 m. The surface of this working face is very flat with relative height less than 20 m, and this area is covered by 12.1–50.62 m thick aeolian sand. The bedrock's thickness of this area is 290–321 m. The bottom elevation of 11203 working face is 826–890 m, while the surface elevation is 1208–1225 m.

* Corresponding author. Tel.: +86 13605218330.
E-mail address: juf1983@163.com (F. Ju).

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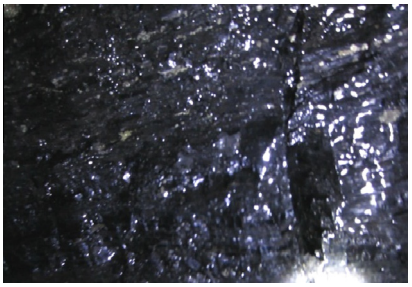

Fig. 1. Pictures of original fracture distribution of coal seam.

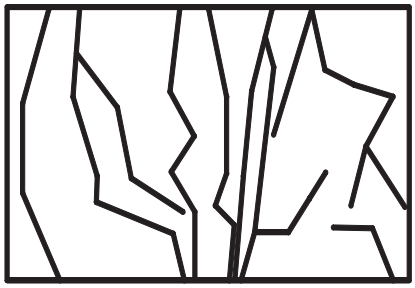

Fig. 2. Overall distribution of surface fracture.

2.2. Roof and floor

The floor of No. 2 coal seam is mostly low strength mudstone, followed by high strength sandstone. The floor consists of weak and soft rock mass inflated in the local area, but it is quite stable on the whole.

2.3. Characteristics of water-rich coal seam

The No. 2 coal seam is the main confined aquifer because of its developed fracture and intense abutment pressure. The normal water inflow of No. 2 coal seam is 100 m^3/h, with the maximum value is 120 m^3/h.

2.4. Characteristic fracture distribution in coal seam

Massive natural fractures are developed in No. 2 coal seam which has turned into the main channels of water inrush and store. The fractures distribute vertically from the top to the bottom, and it can be seen clearly in the surface of No. 2 coal seam. Caused a series of channels between fractures, the special flake occurrence characteristics of coal body are formed in Xiaojihan Coal Mine, as shown in Fig. 1. By analyzing the surface fracture trends of coal body, using sketch reproducing method, the surface fractures distribution of Xiaojihan Coal Mine is shown in Fig. 2.

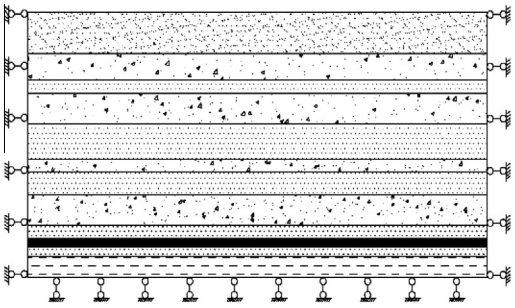

Fig. 4. Numerical mechanical model.

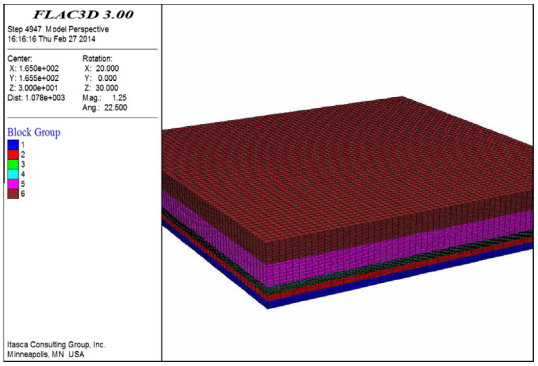

Fig. 5. Mesh of the model.

In order to further observe the internal microcracks distribution in the coal body, SEM (scanning electron microscope) is employed to analyze its internal density, and the SEM images of this coal body under different resolutions are shown in Fig. 3.

As shown in the SEM images, there are a lot of microcracks in Xiaojihan coal body. The structure of the coal body is loose. Because of containing many bulky pores and fractures in the coal body, it has formed some good channels for water storage and water erosion, and also created conditions for the air going into the fractures after water erosion. It is completely different from the dry coal body with higher density.

3. Character of overlying strata behaviors caused by high-intensity mining of the rich aquiferous coal seam

Mining operations could inevitably cause strata movement and damage, which would result in surface subsidence and water and gas flow in coal and rock mass [11–15]. Therefore, studying the

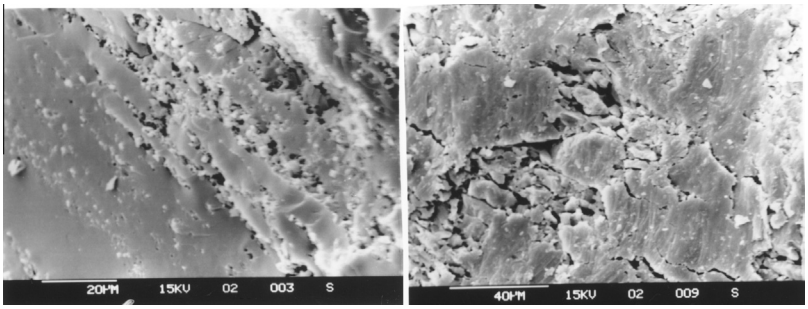

Fig. 3. SEM images of aqueous coal body under different resolutions.