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Prediction of rock-burst-threatened areas in an island coal face and its prevention: A case study

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ABSTRACT

The island coal face arises in coal mines with the purpose of preventing gas explosion or maintaining the balance between mining and tunneling. However, its particular stress conditions in the surrounding rock may increase the difficulty of stress control in the coal face and in its mining roadways, especially when the coal seam, the roof, and the floor have rock-burst propensities. The high energy accumulated in the island coal face and in its roof and floor will intensify rock-burst propensity or even induce rock burst, which further result in great casualties and financial losses. Taking island coal face 2321 in Jinqiao coal mine as a case, we propose a method for the prediction of rock-burst-threatened areas in an island coal face with weak rock-burst propensity. Based on the analysis of the movement of the overlying roof and characteristics of stress distribution, this method combined numerical simulation with drilling bits to ensure the prediction accuracy. The effects of coal pillars with different widths on the mitigation of stress concentration in the coal face and on the prevention of rock burst are analyzed together with the mechanism behind. Finally, corresponding measures against the rock burst in the island coal face are proposed.

1. Introduction

As the depth of coal mines in eastern China increases, new hazards arise from the high underground stress, with catastrophic dynamic phenomena such as rock burst being one of the most unpredictable and violent disasters [1–4]. Rock burst can have a wide variety of adverse effects, such as construction and production delays, damage to equipment, higher costs of construction and operation, and injuries and fatal accidents, and it is thus a subject of great importance to mining researchers around the world [5].

To predict the time and position that rock burst may occur and thus avoid or alleviate the economic loss and physical injuries, a number of techniques (e.g. those employing fuzzy neural networks, rough sets and genetic algorithms, acoustic emission tests, energy balances and induced stress, and geomechanical analogies) have been applied [6–13] and many papers have been published on the prevention of rock burst [14–21]. However, existing studies have largely concentrated on the effects that factors such as mining depth, coal seam thickness and a hard roof and floor have on the occurrence of rock burst, while few studies have considered the effects of engineering structures [22].

In our study, all research has investigated island coal face 2321 in the Jinqiao coal mine, which contains structures such as chambers. In this paper, we investigate the stress field in the island coal face employing numerical simulation. With the combination of a numerical method and the method of drilling bits, the areas potentially threatened by rock burst are located. In the rock-burst-threatened areas, narrow coal pillars and stress relief technology using large diameter drilling and blasting are adopted to prevent the occurrence of rock burst, with desirable results obtained.

2. Analysis of roof movement and stress evolution in the island coal face

2.1. Geological and mining technology conditions

Jinqiao coal mine is located in Shandong province, China. Its island coal face 2321 starts from the haulage roadway and track haulage roadway in the second mining district. It is located between two gobs; the gob of coal face 2311 is to the west and the gob of coal face 2331 is to the east, and there is a protection coal pillar for fault F5 to the north. The average ground elevation

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is +36.9 m, while the underground elevation ranges from −405 to −470 m. To maintain the balance between mining and tunneling, the method of skip-mining is applied, i.e., coal face 2311 is extracted first and coal face 2321 second, which contributes to the formation of island coal face 2321. The relative position of the island coal face is presented in Fig. 1, including the extraction time of coal face 2311 and 2331. Although no rock burst happened during the extraction of these two coal faces, its prediction and prevention is necessary not only because of the particular stress conditions in island coal face 2321 but also because of the weak rock-burst propensity of the coal seam, the roof, and the floor.

With the hardness coefficient f ranging from 2 to 3, the dip angle from 4° to 10°, and the thickness from 5.8 to 6.14 m, the extracting coal seam of island coal face 2321 is coal seam 3, which is characterized by a fractured blocky structure and well-developed joints. Down-dip mining is employed to extract coal face 2321. The immediate roof of coal seam 3 is gray-white medium sandstone with a thickness exceeding 6.8 m. Its main component is quartz, and pyrite can also be found in some parts. With a thickness of no more than 0.8 m, the immediate floor is gray-black blocky mudstone containing a few carbon and pyrite nodules and has a hardness coefficient f = 5–6. The main roof, whose thickness exceeds 10 m, is dark-gray blocky sandstone, with a small amount of siliceous rock included. It has high hardness (f = 7–8) and well-developed joints. Researchers at the China University of Mining and Technology conducted experiments to test the rock-burst propensity of coal face 2321 and its roof using an electro-hydraulic servo testing machine (model: MTS). The results revealed that the energy index for roof bending (U_{WQ}) is 51.83 kJ, therefore the roof has weak rock-burst propensity. The elastic energy index (W_{ET}) for coal specimens is 4.80, the bursting energy index (K_E) is 1.72, the dynamic failure time (D_T) is 144 ms, and the uniaxial compressive strength (R_C) is 5.83 MPa, which indicates that the coal mass also has weak rock-burst propensity. The classification of the level of rock-burst propensity is illustrated in Table 1 [23].

Table 1
Classification of the level of rock-burst propensity.

Level of rock-burst propensity	Bursting energy index (K_E)	Elastic energy index (W_{ET})
Weak	$1.5 \leqslant K_E < 5$	$2 \leqslant W_{ET} < 5$
Strong	$K_E \geqslant 5$	$W_{ET} \geqslant 5$

2.2. Roof movement and stress distribution characteristics

After the extraction of a coal face, the overlying strata will fracture, rotate, and then subside. Therefore, once a coal face is extracted, the main roof of its adjacent coal faces will fracture in a certain position. The distance of such a position to the gob is determined by various factors such as the thickness and the properties of the roof strata. Afterwards, the main roof will rotate and exert stress on the gangue in the gob. With the stress from the roof of the adjacent coal faces continuing to have an influence, a stable arc-shaped triangular block is formed in the mine roadways [24].

Similar movement of the roof in the mine roadway will also occur after the extraction of the coal face on the other side. An island coal face is formed as soon as its adjacent coal faces are extracted and stress concentration in the island coal face is therefore inevitable. The superposed stress is in the shape of an "M"; namely, in the island coal face, peak stress zones will emerge in positions near the mine roadways. The stress distribution in a coal face with one adjacent coal face extracted and in an island coal face is represented in Fig. 2 [25–28], where P is the vertical stress, γ the density of the overlying strata, H the buried depth of the coal seam, and K the concentration factor of the vertical stress.

In Fig. 2a, L_1, L_2, and L_3 illustrate the variation of the lateral abutment stress at three different periods; L_1, a short period, starts from the initial extraction of coal face 2311 to the time point before the stress in the coal wall reaches the ultimate strength and plastic failure of the coal wall occurs. In this period, the lateral abutment stress increases continuously because of the bending and subsidence of the main roof. The coal mass is still in an elastic condition and L_1 shows as a monotonic decreasing curve. Plastic deformation will take place in the coal mass surrounding the coal face instantly after this period. On top of L_1, L_2 lasts until the arc-shaped triangular block of the main roof is formed. In L_2, on the edge of the coal face, the stress in the coal mass reaches the ultimate strength and plastic failure occurs. The bearing capacity decreases considerably and the coal mass enters the post-peak residual strength period. That is why the lateral abutment stress transfers deep into the coal face. Besides, the limit equilibrium area

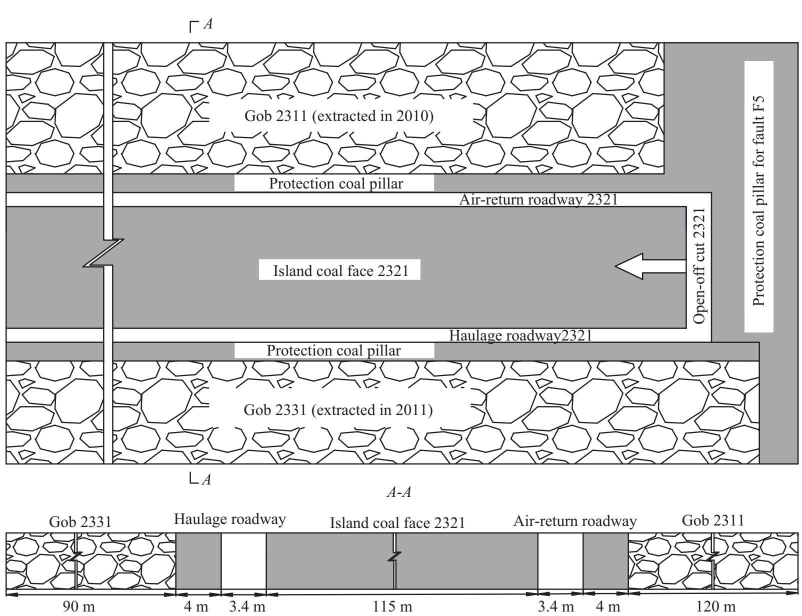

Fig. 1. Sketch map of the location of island coal face 2321.

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