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Stress spatial evolution law and rockburst danger induced by coal mining in fault zone

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ABSTRACT

In order to explore the influence of coal mining disturbance on the rockburst occurring in fault zone, this research constructed a mechanical model for the evolution of fault stress, and analyzed the influence of the ratio of horizontal stress to vertical stress on the stability of fault, and the spatial distribution of the stress in fault zone as well as its evolution rule. Furthermore, the rockburst danger at different spatial areas of fault zone was predicated. Results show that: when both sides of the working face are mined out, the fault zone in the working face presents greater horizontal and vertical stresses at its boundaries but exhibits smaller stresses in its middle section; however, the ratio of horizontal stress to vertical stress is found to be greater at middle section and smaller at boundaries. As the working face advances towards the fault, the horizontal and vertical stresses of the fault firstly increases and then decreases; conversely, the ratio of horizontal stress to vertical stress keeps decreasing all the time. Therefore, if the fault zones are closer to the goaf and the coal wall, the stress ratio will be smaller, and the fault slip will be more prone to occur, therefore rockburst danger will be greater. This research results provide guidance for the rockburst prevention and hazard control of the coal mining in fault zone.

1. Introduction

According to the statistics data of rockburst occurrence, rockburst incidents are likely to occur when working face is close to the geological tectonic zone, concluding that fault is a geologic tectonic which greatly influences the rockburst occurrence [1–3]. Fault rockburst is a phenomenon that an abrupt movement happens at two sides of the fault, leading to intensive energy release; and it is characterized with abundant released energy and high magnitude [4]. With the increase in the intensity and depth of coal mining, the frequency and intensity of fault rockburst greatly improve, resulting in great difficulty in the prevention and control of rockburst hazards [5].

The hazards, which results from fault rockburst under the influence of coal mining, have been received worldwide attention. Jiang et al. considered that the change of the normal stress of fault is always shown to be earlier than that of shear stress under the influence of coal mining. The mining risks in the bottom wall are higher than that in the hanging wall [6]. Li et al. investigated the mechanism of fault-slip because of the influence of coal mining, and they pointed out that fault rockburst is prone to occur when working face located at the bottom wall advances towards the fault zone [7,8]. Song et al. proposed that the occurrence of fault rockburst is associated with the lateral stress on fault; and they concluded that the more the lateral pressure is, the more prone rockburst is to occur [2,9]. Li et al. built a mechanical model of fault locking and unlocking, and proposed that the mechanism of fault-pillar induced rockburst [5,10]. Hofmann et al. introduced Mohr Coulomb's failure criterion into the numerical simulation of static boundary element to investigate the mechanism of the fault-slip movement and mining-induced seismicity [11]. Islam et al. utilized a boundary element mode to explore the stress–strain characteristics for the fault activation due to the mining, and pointed out mining activities lead to the rebalance of fault-stress, which further causes the significant deformation of two fault walls. Meanwhile, great deviatoric stress, which mainly exists in the endpoints of fault, induces the damage of coal and rock mass [12]. Atsushi Sainoki et al. used FLAC3D software to study the different fault-slip degrees with parameters, including different inclinations, buried depths, extraction speeds, stiffnesses and friction angles under the influence of coal mining. They obtained that the parameters, such as inclinations and buried depths, exert great impact on the mining-induced seismicity and energy release of the fault zone [13]. Makoto et al. speculated that: by monitoring the acoustic emission activities in the fault zone, the stress and intensity of fault plane are researched under the influence of coal mining [14].

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As mentioned above, those studies have made many achievements on the fault-slip which induced the rockburst danger (FSRD) under the influence of coal mining. However, little attention focused on the difference in the spatial distribution of fault stress under the disturbance of coal mining. Besides, the characteristics and the difference of the spatial distribution of fault stress on rockburst danger remain unclear. Subject to the limits of geological tectonics and mining technologies, island coal faces are usually formed in coal mining. In addition to the effects of tectonic zone and group stress, the higher stress concentration degree of island coal face tends to cause more violent movement of roof. Thus, rockburst in island coal face is more prone to occur [15,16]. This study took the DF2 fault of the island coal face (No. 7121) at the −1000 m mining depth in Zhangshuanglou Coal Mine as a case study to simulate the disturbance effect of coal mining on the spatial distribution of fault stress in the working face. Using the fault-slip mechanical model analyzed the effect of the spatial difference of the fault stress in the working face on FSRD. Besides, by measuring field data of the mining-induced seismicity obtained in the fault zone under the mining influence, the spatial distribution law of the mining-induced seismicity was analyzed when the working face passed through the fault zone. Afterwards, the law was used to verify the spatial distribution of the stress in the fault zone of the working face, which is conducive to the further studies on the spatial evolutionary law of the fault stress in the working face and FSRD.

2. Introduction of the coal mine

No. 7121 working face in Zhangshuanglou Coal Mine at −1000 level presents an average mining depth of 924 m at 7# main coal seam which contains bituminous coal of medium metamorphic degree with a thickness of 1.5–5.0 m, with the average thickness of 3.68 m. The experimental results of laboratory test on bursting liability of coal showed that: the uniaxial compressive strength is 17.4 MPa; indices of elastic strain energy and burst energy are respectively 9.2 and 4.13; and duration of dynamic fracture of 7# coal seam is 47 ms. According to the *National Industrial Standards of P. R. C*, 7# coal seam exhibited strong impact in addition that severe rockburst once occurred in this coal seam. Thus, the prevention and control of rockburst were given highly importance in the production. No. 7121 working face is 100 m wide. An immediate roof (4.62 m thick mudstones) and a main roof (3.37 m thick fine siltstones) are located above the coal seam. The immediate floor of sandy mudstone is 2.03 m, and a main floor (24.33 m fine sandstone) is located beneath the coal seam. Industrial square protective coal pillar is on west of the working face, with the unmined area on the east, and No. 7123 goaf on the north with a 140 m width, and No. 7119 goaf on the south with a width of 100 m. The DF2 fault, which exerts great influence on the working face mining, is a normal one located at the middle section of the working face. The fault plane that horizontally crosses the working face with a 0–10 m fault throw presented the NE trending and NW-striking with inclination 70°. Fig. 1 shows the layout of the working face roadway.

3. Model and scheme

Based on the influence of coal mining disturbance on the fault activation, the spatial evolution of the fault stress and rockburst danger zone were investigated by the following three aspects, namely effect after mining out the two sides of the working face on the distribution law of the horizontal and vertical stresses; influence of the coal mining disturbance on the evolution law of the horizontal and vertical stresses; and influence of coal mining disturbance on the FSRD.

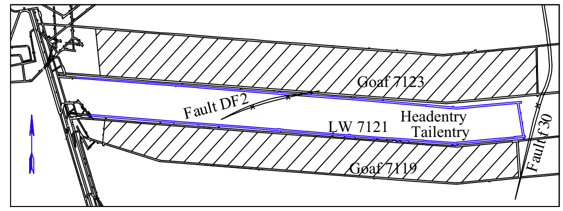

Fig. 1. Layout of the No. 7121 working face roadway.

3.1. Numerical model

A numerical model with a 400 m long inclination, the 400 m long strike and 200 m height was constructed based on the 7121 working face (Fig. 2). The model consists of three parts: 7119, 7121 and 7123 area. The fault zone is located in the middle section of the 7121 area, but there is no fault in the 7123 and 7119 area. Using interface command simulates the fault structural plane.

In Fig. 2, m_1, m_2 and m_3 denote the coal seams; red rectangle f refers to the fault zone; D is the measuring lines which is 5 m away from the fault and parallel to the fault strike, and is set on the roof of the coal seam. Three measuring points (A, B and C) were arranged on the measuring lines to monitor the variation law of the fault stress in the coal face mining process. Among them, the measuring points A and C are 10 m away from both boundaries of 7121 area, while B is located in the middle part of the measuring lines.

Model boundary used the displacement control method. The displacement, both the left and right boundaries along y direction and the front and rear boundaries along x direction, is set to zero. Moreover, the bottom displacement is fixed. The top is set with free surface. Using 20 MPa vertical stress is to replace the dead weight of overlying strata, and 34 MPa horizontal stress is also applied.

Table 1 presents the strata properties used in the model. The properties concluded by considering the real geological information and test results of relevant rock mechanics, as well as the effect of rock mass size. In addition, the Mohr–Coulomb model was taken as the yield criterion of the coal and rock mass.

3.2. Scheme of numerical calculation

In order to simulate the formation states of 7121 island coal face, both sides of 7123 and 7119 areas were set pillars, and the rest of coal seam in the two area was mined out. Then the mining was conducted gradually from the bottom wall towards the fault in the 7121 area. During the mining process, we monitored the stress on the measuring lines and the measuring points.

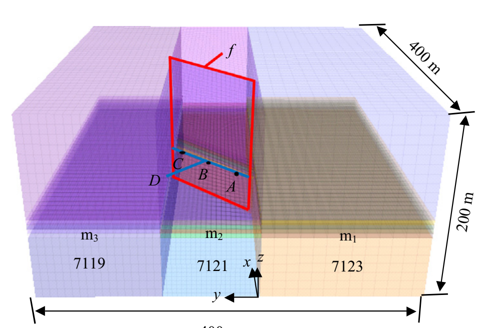

Fig. 2. Numerical model.