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Relevance between abutment pressure and fractal dimension of crack network induced by mining

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ABSTRACT

Based on the geological conditions of coal mining face No. 15-14120 at No. 8 mine of Pingdingshan coal mining group, the real-time evolution of coal-roof crack network with working face advancing was collected with the help of intrinsically safe borehole video instrument. And according to the geology of this working face, a discrete element model was calculated by UDEC. Combining in situ experimental data with numerical results, the relationship between the fractal dimension of boreholes' wall and the distribution of advanced abutment pressure was studied under the condition of mining advance. The results show that the variation tendency of fractal dimension and the abutment pressure has the same characteristic value. The distance between working face and the peak value of the abutment pressure has a slight increasing trend with the advancing of mining-face. When the working face is set as the original point, the trend of fractal dimension from the far place to the origin can be divided into three phases: constant, steady increasing and constant. And the turning points of these phases are the max-influencing distance (50 m) and peak value (15 m) of abutment pressure.

1. Introduction

With working face advancing, the abutment pressure distribution of coal roof has been attributed as a key role for the research of mining engineering and the fundamental theory of mining mechanics [1]. The accurate prediction of the advanced abutment pressure can not only direct coal roof management, tunnel excavation, and coal seam gas extraction, but also has the theoretical value for dynamic accidents related to abutment pressure, such as coal gas outburst, rock and water burst [2,3]. The available methods of measuring abutment pressure includes indirect tunnel deformation and supporting pressure measurement, direct stress measurement, experimental simulation, simplified elastic–plastic or damage constitutional calculation, and numerical calculation based on various hypothesis [4–9]. The above measurements, however, have some drawbacks due to their confined theoretical foundation and cannot represent the real in situ stress field. Thus, the obtained results cannot be applied for real excavation. Hence, Xie at al. proposed that the abutment pressure distribution has significant difference among various mining methods after analyzing a great deal of survey data, and obtained the general law for the three types of typical mining conditions. Wei et al. studied the coal rock stiffness and detected that the fractal dimension of coal with different stiffness has a quantitative relationship with abutment pressure [10]. Xie et al. analyzed the influence of pitch and thickness of coal bed on abutment pressure [8,11]. Qian and Miao proposed the theory of key strata based on the voussoir beam model of strata on longwall working face, and revealed the periodic influence of the key strata breaking on abutment pressure [12,13]. It's well known that fractures initiate, develop, intersect and form a spatial and temporal distributed fracture network with the advance of working face. Consequently, Xie et al. substantiated the fractal characteristics of fracture network in coal roof using analogy simulation, and observed the value of fractal dimension increases with the increasing cut width [14]. Xie et al. logged the fractures on the coal wall of tunnel with working face advancing, and obtained the characteristics of synchronization between fractal dimension and advanced abutment pressure [15].

As stated above, the research of mining abutment pressure from different perspective and different theory conducted by these scholars has a significant effect on engineering, however, the research of abutment pressure distribution from in situ fracture network evolution in coal roof has not been reported in literature. The object of this paper is to obtain the distribution and evolution of fracture network in coal-roof on the condition of deep and inclined longwall mining method, the real-time evolution of coal-roof crack network was collected for three months based on the geological

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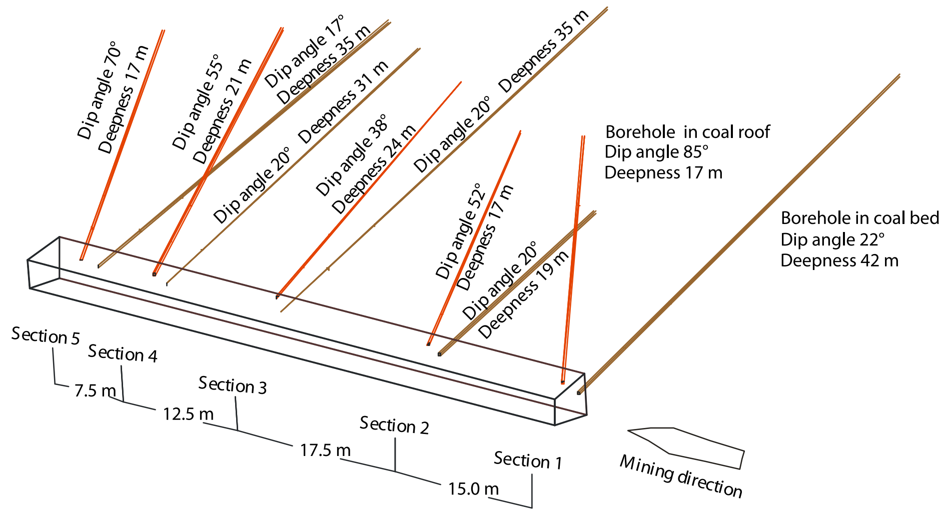

Fig. 1. Three-dimensional distribution of boreholes in situ.

Fig. 2. Borehole video instrument (Ver.TYGD20).

conditions of coal mining face No. 15-14120 at No. 8 mine of Pingdingshan coal mining group. The fractal theory was employed to analyze the time–space characteristics of the fracture network, as well as its relationship with abutment pressure. The discrete element model (UDEC) was used for numerical calculation, and the results agreed well with the former prediction. This rule can be used to direct the design of supporting strategy with great economic value.

2. In situ experiment

2.1. Geological conditions

An in situ experiment was conducted at working face No. 15-14120 in No. 8 mine of Pingdingshan coal mining group, which is one of the thirteen large-scale coal mining bases in China. At the same time, the No. 8 mine located at the east of Pingdingshan city is one of the severest gas outburst mines. The depth of this mining face ranges from 705 to 580 m, and its width is 190 m along the north-south direction. The dip angle of the coal seam is 22° on average, and its mean thickness is 3.6 m. The direct roof is 3.0 m thick mudstone. The gas pressure and gas content of this mining face is 1.6 MPa and 18 m^3/t, respectively. The outburst level dividing method indicates that this working face is prone to coal-gas outburst. Therefore, the research on the generation, development, and evolution of the mining induced fracture network and the passage of gas is critically important.

2.2. Scheme and equipment

The initialization and distribution of fractures in coal bed and strata overburdened are relatively complex on the condition of working face advance. Consequently, it's unpractical to detect fractures in situ and depict their 3D evolution accurately. However, the borehole video instrument can be used to log the fracture evolution on borehole wall every time when mining face advances. Hence, 5 monitoring sections are designed in the tunnel advancing working face No. 15-14120, a borehole perpendicular to roof wall and a borehole along coal bed are placed within each section. The borehole along coal bed was designed to be drilled 40 m deep, 1.5 m high from coal floor, with diameter 75 mm, azimuth and dip angle 211° and 22°, respectively. The borehole perpendicular to roof wall is designed 16 m deep, with diameter 38 mm, located in the middle of tunnel roof. Due to the limited space in tunnel and the occupied volume by mechanical equipment, all the parameters designed for borehole were adjusted except the diameter, and the three-dimensional distribution of boreholes in situ is presented in Fig. 1.

The equipment used in the experiment is the improved borehole video instrument (Ver.TYGD20) as shown in Fig. 2. With an explosion proofing and full HD camera, it can be used to record and shoot borehole wall separation, fissures and factures, as well as voice. The function of antifogging and locating direction was added by the research team to adapt the high-temperature and humid environment in boreholes.

2.3. Experimental results

The deformation of boreholes along coal bed was relatively high due to the low stiffness of coal mass, and some of them collapsed after several days. On the other hand, coal ash shielded the camera during the recording process. As a result, only the boreholes perpendicular to roof wall are analyzed in this paper. With the advancing of working face, the borehole video instrument was used to record the fracture evolution along each borehole wall in roof from the form of the borehole to its total destruction. At the same time, the deepness and direction of camera were logged through the intrinsically safe video recorder, as well as the distance between working face and location of boreholes. Through this way, the real-time fracture network in overburdened strata working face was obtained. In order to analyze fractures quantitatively, the borehole video data with deepness were transformed to