Prediction of Development Height of Water-Conducting Fracture Zone in Pingmei No.12 Mine

ZiHao Wang
School of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo, Henan 454003, China

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Abstract

The determination of the height of the water-conducting fracture zone is of great significance for water disaster prevention and control and efficient coal mining. To study the development law of the water-conducting fracture zone in multi-coal seam mining, taking the development height of the water-conducting fracture zone generated after the mining of the 31040 working face in Pingmei No.12 Mine as the research object, theoretical analysis, numerical simulation, and borehole peeping method were adopted to explore the height of the water-conducting frac-ture zone generated in the 31040 working face. The results show that the height of the water-conducting fracture zone in the 31040 working face is 59m.

Keywords

Water couducting ftacture zone; Numerical Simulation; borehole peeping method

1. Introduction

With the increasing depletion of shallow coal resources in China, deep coal mining will become the new normal to meet the country's energy demand. According to predictions, coal will still play an important role as a stabilizer and cornerstone in China's modern energy system with multi-energy complementarity within the next 100 years. Strengthening the large-scale development of coalbed methane and efficient gas control in major coal mining areas in China will help effectively implement the national "dual carbon" goals of carbon peaking and carbon neutrality. Coal mining is restricted by many adverse factors such as gas, water, dust and geological structures. With the increase of mine excavation depth, the gas content and pressure in the mined coal seams both show an increasing trend, posing a great threat to the efficient and safe production of coal.

Pingmei No.12 Mine is a coal and gas outburst mine with great burial depth, where there are multiple recoverable coal seams that are close to each other. Taking

Pingmei No.12 Mine as the research background, this study focuses on the overlying strata movement and the development height of the "two zones" in the 31040 working face. By analyzing the development characteristics of the "two zones" and the movement characteristics of the overlying strata in the working face roof, the development law of the water-conducting fracture zone above the working face and the movement status of the overlying strata in the working face can be obtained. This research guarantees the safe production of coal mines and also provides a reference for mines with similar geological and mining conditions.

2. Engineering Overview of 31040 Working Face in Pingmei No.12 Mine

2.1. Mine Overview

Pingmei No.12 Mine is located at 80° of the Pingdingshan Municipal Government, with a straight-line distance of about 7.5km, under the jurisdiction of Donggongren Town, Weidong District, Pingdingshan City. The geographical coordinates of the mining area (2000 National Geodetic Coordinate System) are: 113°20′46″～113°24′28″ E longitude and 33°44′33″～33°47′52″ N latitude, with a mining area of 16.7325km^2.

The mine is 7.5km away from the urban area. The Luohe-Baofeng Railway Branch crosses the minefield obliquely, connecting with the Beijing-Guangzhou Railway in the east and the Jiaozhi Railway in the west; the Pingdingshan-Wuyang Branch is connected with the local small railway Luohe-Nanyang Branch; the special railway line of China Pingmei Shenma Group's self-operated mining area runs directly from the main shaft and coal bunker of No.12 Mine to Tianzhuang marshalling station, and is connected with the Luohe-Baofeng Railway. National Highway G311 runs through the central part of No.8 Mine, 4.5km away from No.12 Mine; Ping'an Avenue and Jianshe Road leading to the urban area cross the southern part of the mining area, connecting with G234 in the east. At the same time, simple highways in the minefield are crisscrossed in a network, leading to various cities, prefectures and towns around Pingdingshan City, with very convenient transportation.

2.2. Working Face Overview

The working face is adjacent to the goaf of 31020 in the south, 31060 working face in the north, the boundary of No.10 Mine and No.12 Mine in the west, and the 31040 low drainage inner connecting lane of the lower protective layer and 31020 low drainage inner connecting lane in the east, with the overlying goafs of 31020 and 31040. Overview: The stratum of 31040 working face is a monocline structure with northeast dip, the coal seam strike is 100～120°, the coal seam dip angle is 6～12°, with an average of 9°. A total of 19 faults were exposed during the excavation of the air inlet, return air and open-off cut. The maximum throw of the faults is 5.0m, and the minimum is 0.1m, which have different degrees of impact on mining.

3. Law of Overlying Strata Destruction in Stope

After coal seam mining, the destruction of overlying strata in the stope is a gradual development process from bottom to top, and the degree of destruction of rock strata at different heights is different. According to the damage status of overlying strata, the overlying strata of the stope are generally divided into caving zone, fracture zone and bending zone from bottom to top. The fracture zone is above the caving zone, and the bending subsidence zone is above the fracture zone. Field measurement shows that in the fracture zone, the form and distribution of fractures have certain regularity. Whether under the condition of gently inclined coal seam or steeply inclined coal seam, vertical or nearly vertical bedding fractures generally occur, namely fracture (rock stratum is completely broken) and cracking (rock stratum is not completely broken).

The occurrence and degree of rock fracture and cracking depend not only on the nature and magnitude of deformation borne by the rock stratum, but also on the lithology, layer thickness and its spatial position. The rock strata close to the caving zone are severely fractured; the rock strata far from the caving zone are slightly fractured.

According to the mine overlying strata evaluation coefficient, the lithology of overlying strata in the study area is medium-hard. Therefore, the calculation formula for the height of the caving zone in fully mechanized mining under medium-hard lithology conditions is adopted:

The calculation formula for the height of the water-conducting fracture zone in fully mechanized mining under medium-hard lithology conditions is:

$$H_{li} = \frac{100\sum M}{1.6\sum M + 3.6} \pm 5.6 \tag{1}$$

$$H_{li} = 20\sqrt{\sum M} + 10 \tag{2}$$

Where: M — mining thickness

4. Numerical Simulation Analysis

4.1. Establishment of Numerical Model

A corresponding simplified numerical model was established according to the 22-13 drill hole column diagram. The model is divided into 52 layers with a length of 500m. The coal seam to be excavated and the protective layer are located in layers 38, 40 and 42 respectively, with an excavation length of 180m and the thicknesses of the three excavated layers are 3.3m, 2m and 1.7m in turn. The established model is shown in Figure 1.

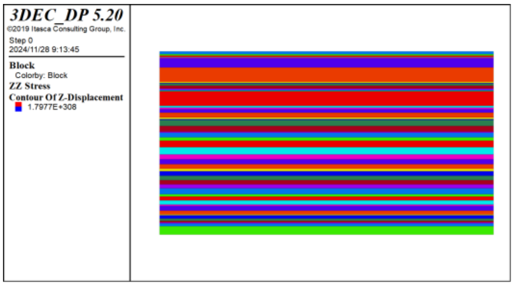


Figure 1. Numerical Model of Roof and Floor Rock Strata Structure of Coal Seam in 31040 Working Face

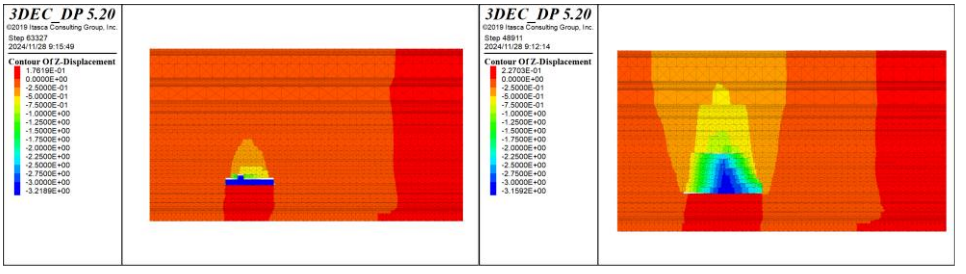
4.2. Plastic Zone Distribution with Working Face Advancement

The distribution of the plastic zone with the advancement of the working face is shown in Figure 2.

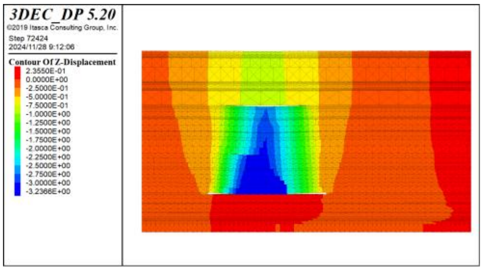
Figure 2 Plastic zone distribution of working face with comprehensive mining height of 3.3m as the working face advances.

It can be seen from Figure 2,the distribution diagram of the surrounding rock plastic zone, that with the mining of the working face, the scope of the plastic zone above the goaf gradually increases and becomes stable after reaching

180m. The area in the plastic flow state is mainly concentrated within 60m of the overlying rock strata. Most of the upper area of the mining area is in shear yield failure.



(a) Tunneling 60m (b) Tunneling 120m



(c) Tunneling 180m

Figure 2. Distribution of Plastic Zone in Working Face with a Comprehensive Mining Height of 3.3m as the Working Face Advances

4.3. Simulation Results

After coal seam mining, the overlying rock strata can be divided into 4 zones from bottom to top:

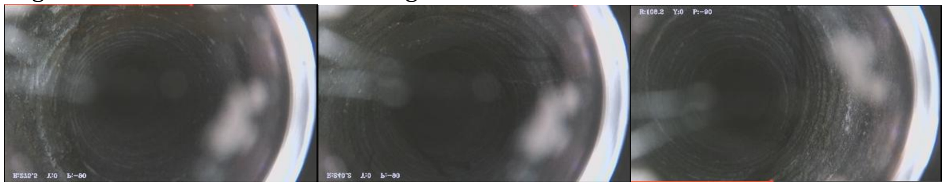
1. Tensile failure zone (i.e., caving zone): Under the action of tensile stress, the rock strata are pulled apart and produce large deformation, and the rock strata are mainly caved.
2. Tensile fracture zone (i.e., water-conducting fracture zone): The tensile stress in a certain direction exceeds the tensile strength of the rock mass, resulting in tensile fractures in a certain direction.
3. Plastic deformation zone (lower part of the bending zone — separation zone): Ductile rock strata undergo plastic deformation, and brittle rock strata undergo shear failure.
4. Elastic zone (bending deformation zone): The rock mass does not undergo any damage under the influence of mining.

The tensile failure zone mainly refers to the rock strata above the goaf, and the tensile failure zone is divided into the caving zone. Tensile fracture zones develop in the upper part, producing unidirectional or bidirectional fractures, which divide the tensile fracture zone into fracture zones. The plastic deformation zone and elastic zone can be divided into the bending subsidence zone.

Therefore, the height of the rock stratum where the rock stratum stress exceeds the yield strength or shear strength and starts to undergo plastic deformation or shear failure is defined as the upper limit of the fracture zone, and the height of the rock stratum where the bidirectional tensile stress of the rock stratum exceeds the tensile strength and starts to undergo large deformation is defined as the lower limit of the fracture zone. The height of the water-conducting fracture zone is between the upper and lower limits of the fracture zone. The water-conducting fracture zone is in the range of the tensile stress area, and its tensile strain exceeds a certain value, so that the tensile fractures are connected with each other to form the water-conducting fracture zone.

5. Field Measurement by Water Injection Leakage Method

Borehole peeping was carried out on No.1 borehole. The peeping results show that when the peeping probe enters 25m of the borehole (Figure 3 (a)), the borehole wall is intact with only some tiny primary fractures, indicating that it has not entered the influence range of the goaf at this time; when the peeping probe enters 44m (Figure 3 (b)), there are large fractures and some primary fractures on theborehole wall, indicating that it has entered the influence range of the goaf at this time. Therefore, it is determined that the subsequent boreholes have successfully entered the goaf range. Combined with the borehole trajectory, it is determined that the designed boreholes are in the influence range of the goaf. Finally, the disappearance of fractures was observed at 57 meters of the borehole (Figure 3 (c)), indicating that it began to leave the water-conducting fracture zone.



(a) 25m (b) 44m (c)57m

Figure 3. Peeping diagram of No.1 borehole

6. Conclusions

(1) The fracture distribution characteristics of the overlying rock strata after caving in the working face were analyzed by theoretical analysis method, the geometric model of rock stratum bending subsidence was established, and the correctness of the downhole double-end water plugging test results was verified according to the measured results.

(2) According to the empirical formula, the coal seam roof of No.12 Mine is medium-hard rock stratum. The calculated height of the caving zone is 18.3~22.7m, and the height of the water-conducting fracture zone is calculated by the formulas, which is 42.5~58.3m for the 31040 working face.

(3) The double-end water plugging leakage method was used for field measurement of the 31040 working face. The maximum development height of the water-conducting fracture zone in No.1 borehole is 57m, that in No.3 borehole is 5m, and that in No.4 borehole is 59m.

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