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Study on Numerical Simulation of Resistivity Response Characteristics of Surrounding Rock During Coal Seam Mining

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Abstract

Aiming at the problem of rock resistivity change in mining process of coal face, based on the related physical parameters of 8103 working face in Baizhuang Coal Mine, the mining model is established by Flac3D, the distribution of mining stress and plastic failure area are simulated, and the stress variation law of surrounding rock in mining process is analyzed. On this basis, combined with supersonic High-density cross-hole perspective technology can dynamically monitor the water-rich situation, water flow and floor failure depth of mine roadway under the influence of mining and stress, and obtain the variation trend of surrounding rock resistivity during coal seam mining, which provides new experience for the accuracy of inversion of mine resistivity data.

Keywords

Numerical simulation, Stress analysis, Ultra-high density resistivity method, Floor failure depth, Cross-hole spatial perspective technology.

1. Introduction

The electric water exploration technology in the special underground environment is mainly based on the electrical conductivity difference between underground geological bodies, and then delineate the low resistance abnormal area [1], but the magnitude of the stress on the rock will also change the electric field response. At present, many researchers have carried out in-depth research. Cheng Jiulong [2] (simulated the change of resistivity characteristics of overburden in different periods of mining activities, The response relationship between the deformation and failure of overburden and the change of resistivity is obtained; Wu Rongxin [3] uses the three-dimensional electrical method of ground drilling with parallel electrical instrument to detect the water diversion channel of coal mine limestone; Gao Weifu [4] uses FLAC3D to simulate the coal seam head-on ahead stress to compare the resistivity of rock, which shows that the stress affects the conductivity of stratum; Tu jienan [5] analyzes the load-bearing deformation of rock The evolution law of resistivity in the process of fracture is deduced, and the expression of the ratio of resistivity sudden change stress and peak stress of rock before fracture is derived; Wang Enyuan [6] analyzes the response law and change mechanism of coal resistivity in different stages of total stress-strain; Yang Cai [7] studies the time domain and the peak stress of coal and rock during mining based on the principle of time domain and frequency domain electrical exploration Electrical characteristics in frequency domain. In this paper, FLAC3D software is used to simulate the change and distribution of stress in the process of coal mining, and to analyze the law of change of resistivity, lithology and pressure, so as to provide the basis for the application of resistivity method in the exploration of water in the complex hydrological working environment with high pressure.

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2. Organization of the TextLaw of Electrical Property Change of Surrounding Rock Caused by Stress

In the laboratory, the change of rock resistivity with stress is very obvious [8], different rock change laws and change ranges are different, the change of sandstone resistivity with stress is complex, and the change range is large; the resistivity of mudstone will slowly decrease with the increase of stress; the change range of limestone resistivity with stress is small [9] [10]. In the process of coal mining, the goaf is increasing, the original stress balance of the surrounding rock is broken, and the stress of the surrounding rock will be redistributed under the action of gravity, which will cause the surrounding rock to move, mainly including the deformation and destruction of the coal seam itself, the destruction of the coal seam floor and the caving and deformation of the coal seam roof, until the stress reaches the balance again [11]. In the process of stress re balancing, the resistivity of surrounding rock will also change. However, there are many problems in engineering application, the direction of water movement caused by stress response in mining process can not be determined; the limitations of electrode layout in the working site; and the underground environment can not simply apply the change relationship between stress and resistivity, the surge and release of stress in the mining process of the working face will damage the rock stratum, forming fracture zone and water rich channel, especially in the high pressure and complex hydrogeology Under the condition, it will change the characteristics of electric field greatly, and bring difficulties to the inversion and interpretation of electric data.

3. Numerical Simulation of Mining Stress in Coal Seam

3.1 Establishment of FLAC3D Numerical Simulation Model

The three-dimensional numerical calculation model is based on the actual geological conditions of 8103 working face in Baizhuang coal mine, combined with the principle of geological body simplification. It is generated by the generate command of FLAC3D numerical simulation software. The whole model is composed of hexahedral grid. The advancing direction of the working face is the positive direction of x-axis, the inclined length direction of the working face is the positive direction of y-axis, and the z-axis direction is set in the vertical direction perpendicular to the direction of the working face. The model size is x × y × z = 400 m × 150 m × 100 m. according to the data of the working area and the boundary effect after mining, 50 m protective coal pillars are reserved at the strike end of the working face, and 25 m protective coal pillars are reserved at the inclined end. Brick element is used to simulate the coal seam. The front, back and side of the model are fixed to limit its horizontal movement, the bottom of the model is limited to its vertical movement, and the top is applied with the equivalent load of the overlying strata:

$$p = \gamma H \tag{1}$$

Where: γ——Average unit weight of overlying strata，0.025 MN/m^3;

H——Mining depth, m;

p—— stress, MPa;

The thickness of the model coal seam is set as 2 m, and the 8 coal seam in the study area can be generalized as near horizontal coal seam; the equivalent load of the overburden is taken as the stress boundary condition of the top interface; the various layers in the study area are generalized as 27 layers, and the physical and mechanical parameters of each layer are set according to the geological drilling test data in the study area.

3.2 Coal Seam Mining Simulation

The excavation method of this coal seam mining simulation is step-by-step excavation, with a step distance of 10 m, a total of 16 steps, and a total excavation length of 160 M. This paper mainly analyzes and studies the change and process of floor strata when the coal seam is 40 m, 100 m and 160 m, so as to judge the depth of floor failure and the risk of water inrush.As shown in Figure 1,

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when the coal seam is mined for 40m, the stress is concentrated in front of the mining position, which is in the state of stress increase and micro stress display, which is the compression area; the stress of the bottom plate in the back goaf is obviously reduced, and the rock mass changes from the original compression state to the expansion state, which is the expansion area; near the boundary between the expansion area and the compression area, the bottom plate rock mass is damaged by shear stress [12] [13]. In the compression area, the rock stratum is affected by the mine pressure, the water in the rock stratum is squeezed outwards, the rock stratum resistivity is reduced; in the expansion area, the rock stratum is likely to be sheared and damaged due to the reduction of stress, the water rich channel is increased, and the rock stratum resistivity is reduced. At the same time, there is a similar stress concentration phenomenon behind the cut hole of the working face, but the stress concentration behind the cut hole is caused by the accumulation of strain energy caused by the slow release rate of strain energy stored in the coal body from the coal wall during the mining process [14], which will make the rock crack gap compressed and the resistivity reduced. When the coal seam is mined for 40 m, the damage depth of the floor is about 13 m, as shown in Figure 2, when the coal seam is mined, the damage effect of the floor strata is mainly concentrated in the middle of the goaf, and the plastic slip area in the middle of the goaf is expanding to both sides of the deep.

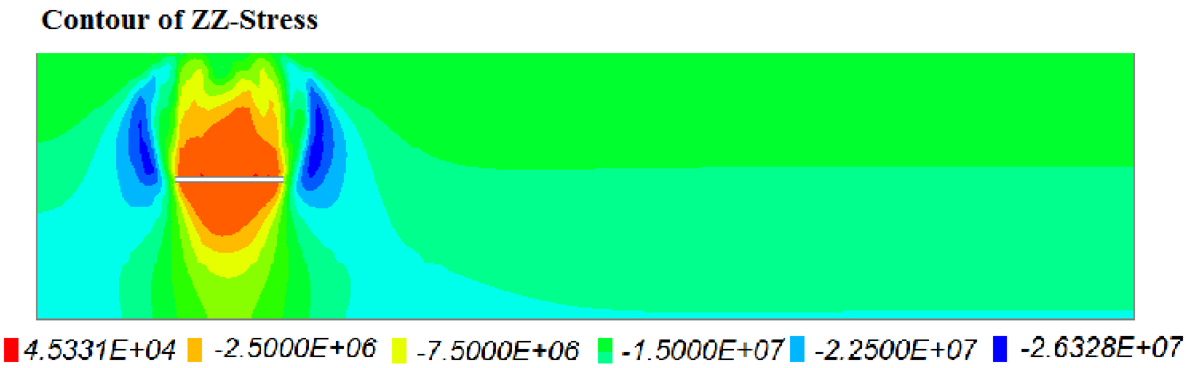

Figure 1. Stress distribution at 40 m

Figure 2. Distribution of plastic zone at 40 m

When the coal seam is mined for 100 m, the bearing stress of the coal pillar increases continuously (Fig. 3), which further develops the fracture. When the water enters the fracture, the rock resistivity decreases, and when the fracture contains air, the rock resistivity increases. As shown in Figure 4, the scope of plastic failure area of the overlying strata and the floor of the working face is further enlarged, the tensile crack of the roof develops to the middle, and the plastic failure of the floor is mainly the shear failure around the goaf, with the failure depth increasing to 22 m. The degree of damage decreases with the increase of the depth from the coal seam floor. However, because of the further deepening of the weak surface, the confined water from the coal seam floor may enter the floor, and the resistivity of the surrounding rock around the goaf may decrease, showing a low resistance anomaly.

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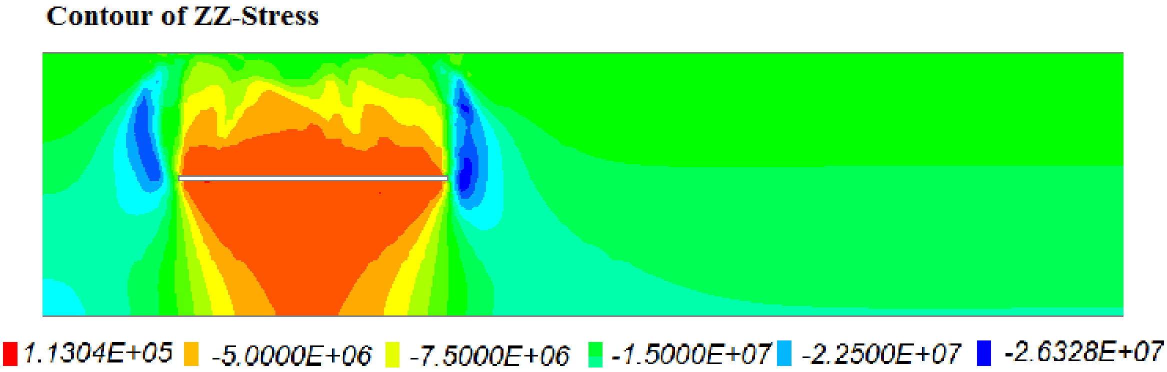

Figure 3. Stress distribution at 100m advance

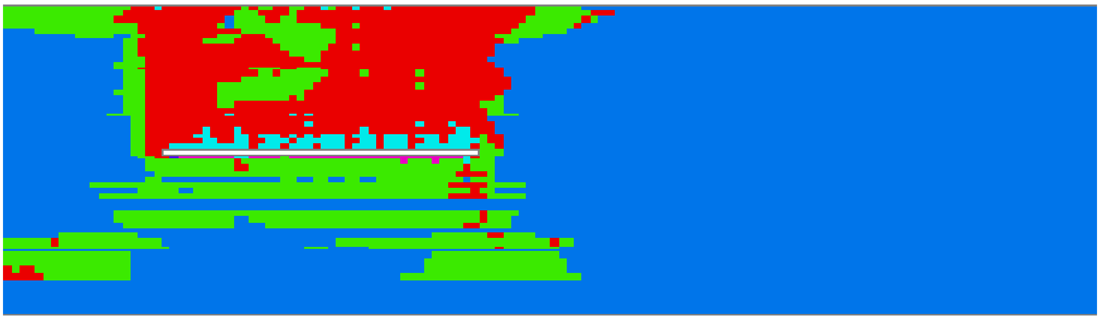

Figure 4. Distribution of plastic zone at 100m

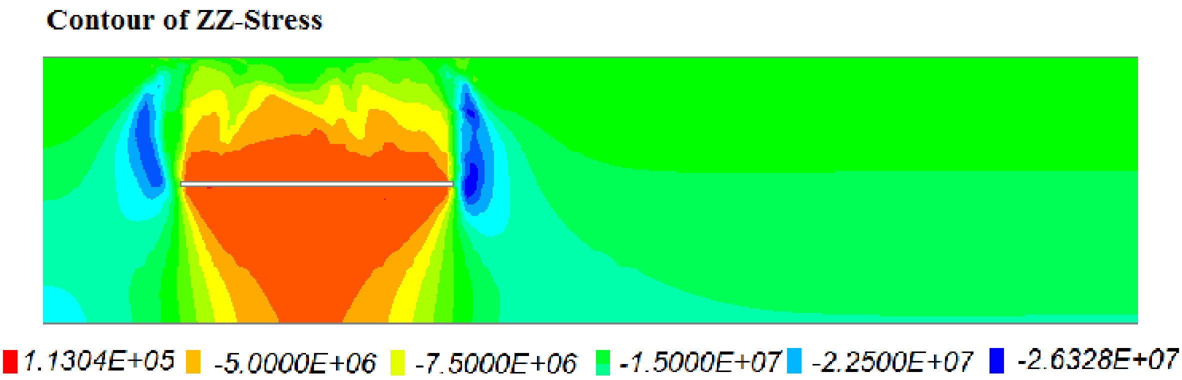

Figure 5. Stress distribution at 160 m

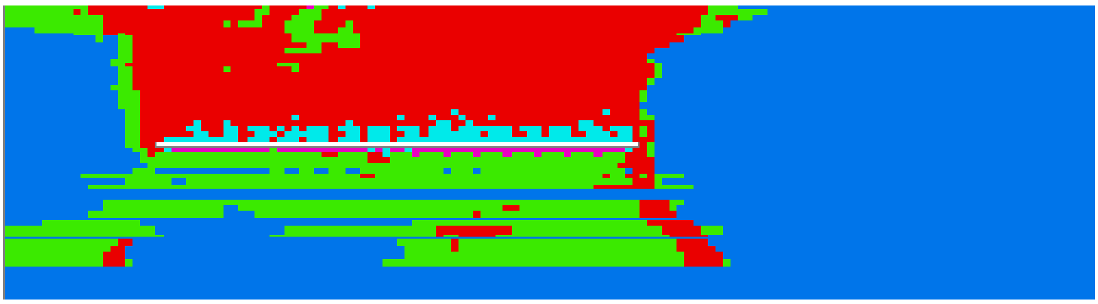

Figure 6. Distribution of plastic zone at 160 m

When the coal seam is mined for 160 m (Fig. 5), the stress in the goaf is gradually reduced, the stress concentration phenomenon is reduced compared with that before, the stored strain energy is released slowly, the expansion area in the goaf is gradually transformed into the compaction area, the conductivity of the rock layer is gradually increased, the resistivity is gradually reduced from large

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to small, and the resistivity of the surrounding rock is gradually restored. As shown in Figure 6, the scope and depth of plastic failure area of the overlying strata and the underlying strata are further increased, the fractures are connected, the old roof periodically collapses, the downward bending fractures of the overlying strata are increased, and the resistivity of the strata is reduced. When the depth of floor failure increases to 26 m, the fractures connect the five ash strata. The mining fractures in the cut hole and the floor in front of the coal wall are relatively developed, which is easy to form water inrush points, so the resistivity of the two strata decreases.

4. Engineering Application and Verification

Baizhuang coal mine is located in Feicheng City, Shandong Province. The 8103 working face explored this time has a horizontal length of 100 m, a push mining length of about 250 m, a mining elevation of - 430 m, and a coal thickness of 1.9 M. the construction of the working face is mainly threatened by the pressure water of five ash and Ordovician ash.This time, the method of cross hole ultra-high density resistivity measurement is used, combined with the change of mine pressure, and the dynamic monitoring is carried out along with the mining of the working face. The instrument used for data acquisition is flash res64 ultra-high density electric tester, which has electrode cables of cable1 and cable2. Data is collected by notebook with high measurement efficiency. This measurement is based on the four-level electrode arrangement mode, and the data of the device is fully collected [15]. In order to ensure the safety of the cable and the convenience of construction during the survey, a single lane, inclined span hole observation deviceis designed on the basis of the grouting transformation work drilling. Among them, the spacing between 1 and 2 holes is 90 m, the hole depth is 160 m, the inclination of 1 hole is - 39 °, and the inclination of 2 holes is - 41 °. The electrode spacing in the drilling is 5m. In order to ensure the contact area, each electrode is welded with a metal sleeve. After the electrode layout is completed, the high-pressure grouting is carried out to seal the hole and fix the electrode, so as to avoid the influence of coal mining on the measurement and reduce the measurement error.

Before data inversion, it is necessary to preprocess the data. By observing the distribution of current pairs, the abnormal current points are eliminated. At the same time, the data quality threshold is set to remove the variation data points and iterate until passing. After data inversion, surfer software is used for mapping, which is the final imaging result map. As shown in FIG. 7 (a), this is the resistivity inversion map of 1 and 2 boreholes before mining. According to the drilling formation data, the high resistance abnormal area in the middle of No. After the working face near borehole 1 is cut through, the floor stress around the cut roadway increases, the rock fracture is compressed, and the flow direction stress of water decreases, resulting in the increase of shallow resistivity at borehole 1 and the low resistance in the middle. Figure 7(b) represents the resistivity inversion map when the working face has been pushed forward 96 M. It can be seen from the figure that within 20 m in front, due to the influence of mining, the rock stratum is forced and squeezed, and the rich water body is divided, so the rock stratum within 20 m in front presents a high resistance area. Because the mine pressure curve propagates forward and downward, the variation trend of resistivity isoline is similar to that of mine pressure distribution. At the same time, in the mined out area behind the mining location, due to the poor conductivity of the rock in the rear caving area, there is a high resistance area; in the expansion area, the rock is not compacted, and the conductivity of the rock is also poor, showing a part of the high resistance area; with the gradual recovery of the stress in the mined out area, the rock is gradually compacted, and its conductivity is gradually strengthened, showing a part of the low resistance area. Figure 7 (c) represents the resistivity inversion map when the working face has been pushed forward 96 M. In the compaction area, due to the stress recovery of the original rock stress, the cracks open, and the water in other places enters the goaf with the cracks. As time goes on, the water in the goaf is increasing, and the internal resistivity is also decreasing, becoming a low resistance area. The gentle gradient of the resistivity isoline shown in the figure just proves the movement and change of water into the fracture. At the same time, the electrical response of goaf and surrounding rock can be inferred from the numerical marks.

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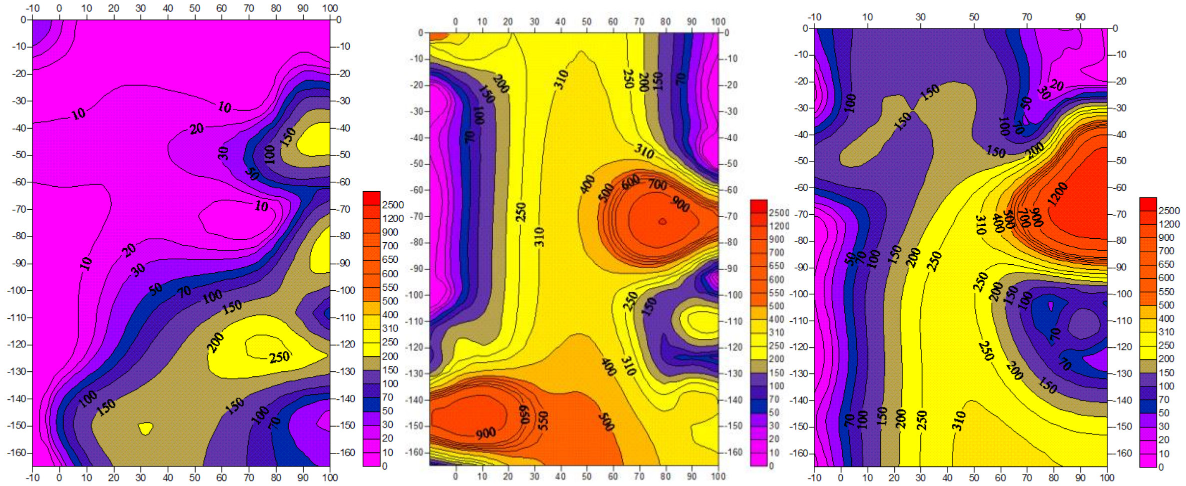

(a) undrawn (b) mining 96 m (c) mining 230 m

Figure 7. Inversion of cross hole ultra-high density electrical method

5. Conclusion

Using FLAC3D simulation software, the 8103 working face model is established based on the measured data. The stress distribution and floor damage development law are studied during coal mining. The resistivity change trend corresponding to the stress distribution is established. The water body in the stress concentration rock gap in the compression area is squeezed out and the resistivity increases. At the same time, the stress may cause damage to the rock mass, resulting in the decrease of resistivity relative to the original rock after the compression zone is transformed into the expansion zone.The application of cross hole ultra-high density resistivity method in water exploration of 8103 working face has delineated the water rich area of the working face, verified the feasibility of resistivity method to detect the anomaly caused by the change of mine stress, obtained the migration law of stress to the water body of rock stratum, provided new experience for underground water exploration, and developed new methods for underground water prevention and control.

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