Research Article

Research and Control of Underground Pressure Law of Coal Mining Face in Soft Rock Strata Based on Neural Network under the Background of Wireless Network Communication

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Our country has a vast territory and rich resources, but it is a country with more coal, less oil, and poor gas. With the increase of our population, the development of society, and the more severe international situation, coal has become more important for our country's economic development and energy. Security plays an irreplaceable role. Based on the neural network, this paper studies and controls the underground pressure law of the coal mine's soft rock heading face, aiming at the safe and efficient mining of the first face and providing an experience for the next face. This paper mainly uses BP neural network learning algorithm and support pressure algorithm to measure and study the ground pressure law of coal mine soft rock heading face and establishes the ground pressure online monitoring system, which is used to analyze and summarize the ground pressure abnormal area during the mining of the working face, so as to provide the basis for safe mining of the working face. Through the field measured data, the initial pressure step and periodic pressure step at the upper, middle, and lower parts of the working face, the average working resistance of the support at the working face during pressure, and the dynamic load coefficient of the support are obtained. It is analyzed that the support in the middle of the working face has a large load and the pressure is obvious. The experimental results show that the initial support force of the whole working face is approximately normally distributed, the proportion of the initial support force in the range of 10–30 MPa accounts for more than 85% of the total statistics, and the frequency of the initial support force in the upper, middle, and lower stations at 10–25 MPa is 55%–65%.

1. Introduction

1.1. Background. Coal is the most important one-time energy source in our country, and it is a prominent bottleneck restricting our country's economic development. In recent years, with the national macrocontrol, our country's total coal consumption has gradually begun to decrease. It is predicted that coal will still account for about 50% of primary energy consumption by 2050. The pattern will not change much. With the development of the coal industry, extensive attention has been paid to the exploitation and utilization of resources, and the mining of various complex coal seams has gradually been paid attention to. In recent years, the mining of close-range coal seams has also been paid attention to by scholars from all sides. There are two

main reasons for this. On one hand, because of China's rich coal resources, vast territory, and vastly different coal seam structures, some coal mines in Shanxi, Inner Mongolia, Anhui, and other places have some problems with the mining of soft rock formations. On the other hand, because coal is a nonrenewable resource, China has been mining coal for many years, resulting in a gradual decrease in the reserves of easy-to-mine coal seams in some mining areas. At the same time, there are some mining areas. Due to the backward technology and equipment in the early stage, some of the short-distance coal seams that have not been mined are left. With the advancement of mining technology, with the development of supporting equipment, it is necessary to effectively recover this part of the resources, not only to protect the resources but also to extend the use time of the

mining area. The pressure display of the mine during coal seam mining and how to control the pressure have always been hotspots in scientific research and engineering at home and abroad, but it is a pity that most domestic research stays on a relatively shallow single coal seam face. Regarding the behavior of underground pressure in deep layers, the foundation layout and support protection methods of the lower coal seam roadways are mainly improved under the condition of close mining. These are based on engineering research, and there is little research on theoretical laws, which is the focus of this paper.

1.2. Significance. Chinese scholars have conducted a lot of research on related issues under coal mine soft rock mining conditions. According to the search results of HowNet, there are more than 10,000 pieces of research literature on close coal seams from 1963 to 2016. After 2000, it is a stage of rapid development. The number of documents has shown exponential growth. Since 2015, there are more than 1,000 research documents on coal mine soft rock mining every year. The above research results provide us with a better understanding of various problems in close coal seam mining. It also shows that the research boom in coal mine soft rock mining is still continuing at this stage. Although a lot of beneficial results have been achieved for the related problems of close coal seams, the various research directions of mining engineering show an unbalanced state. According to the keyword word frequency ranking results of the related literature on short-distance coal seams on HowNet, the top 20 rankings are numerical simulation, short-distance coal seam, goaf, gas drainage, coal and gas outburst, close-distance coal seam group, upward mining, gas drainage, gas control, close distance, roadway layout, roadway support, extremely close coal seams, coal mines, gas drainage, protective layer mining, bolt support, rockburst, mining pressure manifestation, and fully mechanized mining face. Among them, there are nearly 600 articles on gas drainage and treatment, 350 articles on roadway layout and support, and only 95 articles on working face. Among them, there are very few related to working face rock pressure law and its control. The laws of mineral pressure appearance under the condition of the distance coal seam and the related theory of its control are not mature and perfect, and there is still a certain degree of blindness in the mining of the coal face near the coal seam. Therefore, it is necessary to systematically and in-depth study the behavior and control of rock pressure under the condition of short-distance coal seam mining, especially the research on the behavior and control of rock pressure on the lower coal face under the condition that the upper coal seam has been mined.

1.3. Related Work. Coal plays an irreplaceable role in our country's economic development and energy security. Yan et al. depended on a large amount of measured data of Qingdao Metro Line 3, which analyzes and studies the law of ground subsidence in large-span shallow-buried excavated stations. Through data fitting, it is found that the regression analysis of the first-degree cubic polynomial can get a better

fitting effect. This study has accumulated a large amount of surface settlement monitoring data, which can provide a certain reference for the subsequent design of similar lines [1]. Lv et al. used the shield tunnel project from Tongdewei Station to Shangbu Station of Guangzhou Metro Line 8 as the research background and used finite element simulation and field monitoring research methods to analyze the influence of shield tunnel construction on ground settlement under different conditions. The research results can provide a reference value for similar shield construction in the upper soft and lower hard composite stratum [2]. Jian et al. proposed that the cooling capacity of the fan of the air-cooled condenser (ACC) will be affected differently by exhaust gas recirculation and axial coupling in different areas. This is done by using fan clusters to pump water and using computational fluid dynamics (CFD) methods. The research results show that although the ventilation of the fan is large, the heat transfer efficiency of the fin tube bundle of the air-cooled unit is not necessarily high, which can provide a theoretical and experimental basis for further research on the control of the air-cooled island axial fan [3]. Wu et al. tried to explain the influence of the confining pressure-related Young's modulus on the ground response analysis of mountain tunnels. Based on the fourth Runge-Kutta method, a semianalytical solution was obtained. Considering the influence of confining pressure on Young's modulus, analytical and numerical methods are used to calculate the stress and deformation of the rock mass around the tunnel [4]. Based on field tests, case studies, and numerical modeling, Zhang et al. conducted a comprehensive investigation of the ground stability of the deep gate road buried 1 km deep. The in situ stress measurement and mechanical performance test were first carried out at the test site. Then, FLAC3D software was used to simulate the deformation behavior of the doorway, the distribution of stress and yield zone, and the bolt load. The model results show that soft rock properties and high in situ stress are the main factors for deep gate instability, and shear slip failure caused by high stress is the main failure model for deep rock masses [5]. Zhang et al. proposed that geothermal exchange and temperature field changes are complex, with moving boundaries, internal heat sources, and phase changes. Under the premise of ensuring the safety of freezing construction, it is important to reasonably determine the freezing area and freezing temperature. The author summarized the research methods of the cross-channel freezing method and introduced the frozen undisturbed soil constitutive model and the calculation theory of the frozen wall, so as to deepen the understanding of the deformation mechanism of the cross-channel buried in the soft soil due to freezing and thawing [6]. Although the analysis process and theories are valuable, the theories presented lack practical value.

1.4. Innovation. The innovation of this paper is as follows: (1) First is the innovation of the topic selection angle. This paper is a new perspective from the perspective of topic selection. At present, there are not many researches that integrate wireless network, neural network, coal mine soft

rock formation, working face, and mine pressure law. It is of exploratory significance. (2) The second is the innovation of research methods. This paper uses the BP neural network learning algorithm and support pressure calculation to study the ground pressure law of the coal mine's soft rock heading face, which has high theoretical value and exploratory significance. (3) In addition, it is the innovation of project practice. This paper studies the law of mineral pressure, the development law of overburden cracks, and the development characteristics of surface cracks during the mining of the 8101 working face of Selian No. 1 Mine, which are important for the safe and efficient mining of the first mining face and for the next work. The mining of the surface provides experience with greater theoretical and practical significance.

2. Related Technology

2.1. BP Neural Network Learning Algorithm. The computation process of the BP neural network consists of forward and backward computation processes. In the forward propagation process, the input pattern is processed layer by layer from the input layer through the hidden unit layer and shifted to the output layer, where the state of neurons in each layer only affects the state of neurons in the next layer. If the desired output cannot be obtained in the output layer, it is shifted to the backward propagation, where the error signal is returned along the original connection path, and the error signal is minimized by modifying the weights of each neuron.

The specific BP algorithm is derived as follows: suppose the input layer has P neurons [7] and p is any neuron among them; the hidden layer has V neurons, and v is any neuron among them; the output layer has C neurons element, and c is any neuron among them. E_{pv} represents the salience weights of the p -th neuron in the input layer and the v -th neuron in the hidden layer, and E_{pc} represents the salience weights [8] of the p -th neuron in the hidden layer and the v -th neuron in the output layer [9].

The error signal of the p -th neuron in the output layer is

$$n_{kp} = q_{kp}(b) - x_{kp}(b). \quad (1)$$

Define the mean square error of neuron p as $(1/2)n_{kp}^2(b)$, and then the sum of the errors of all neurons in the output layer is

$$H^k(b) = \frac{1}{2} \sum_{m=1}^M n_{kp}^2(b). \quad (2)$$

When all samples are entered once, the total error is

$$H(b) = \frac{1}{2} \sum_{k=1}^N \sum_{p=1}^P b_{kp}^2(b). \quad (3)$$

When the network's learning error is obtained after it fails to achieve the expected level of accuracy, from which it will enter the backpropagation of the image. Over the propagation process, each neuronal layer's weights are in constant modification to gain the wanted accuracies [10].

The weight of the network is corrected according to the method of gradient descent of the error function [11], that is, $\Delta E_{pv}(b) = -\mu(\ell W(b)/\ell E_{pv}(b))$ (where μ is the learning step size) to adjust the weight of the network [12]; you can get

$$\frac{\ell W(b)}{\ell E_{pv}(b)} = \frac{\ell W(b)}{\ell a_{km}(b)} \cdot \frac{\ell y_{kp}(b)}{\ell x_{kp}(b)} \cdot \frac{\ell x_{kp}(b)}{\ell u_p^p(b)}. \quad (4)$$

Let the local gradient be

$$\mathfrak{R}_p^P(b) = \sum_{k=1}^N \sum_{p=1}^P \sum_{v=1}^V a_{kp}(b) f(I_p^P(b)). \quad (5)$$

When the excitation function adopts formula (4), then

$$f'(a) = f(a)(1 - f(a)). \quad (6)$$

Thus,

$$f'(u_p^p(b)) = \frac{\ell C_p^P}{\ell u_p^p(b)} = V_p^P(b)(1 - V_p^P(b)) = y_{kp}(b)(1 - y_{kp}(b)). \quad (7)$$

According to the Delta learning rules, the correction amount of $E_{pv}(n)$ is

$$\Delta E_{pv}(n) = -\mu \frac{\ell E(b)}{\ell E_{kp}(b)} = \mu \sigma_p^P(b) V_c^C. \quad (8)$$

In the formula, μ is the learning step length, $\sigma_p^P(b)$ can be obtained by (7), and V_c^C can be obtained by the signal's forward propagation process formula (7). Then, the weight between the neurons on the hidden layer P and the output layer V in the next iteration is

$$E_{pv}(b+1) = E_{pv}(b) + \Delta E_{pv}(b). \quad (9)$$

2.2. Basic Neuron Structure. The basic component of the neural network model [13] is the neuron. The neuron has a basis function and an activation function [10]. With the base function as the multi-input single-output function, its role is to be mapped nonlinearly to the output of the base function. By the design of the mapping function, the product reaches a specified range of outputs. The characteristic of this nonlinear transformation is of prime importance for a synthetic neuron. In this way, it makes it possible for these networks to deal with complex and complicated problems.

For common basis functions, there are generally the following options.

2.2.1. Linear Combination. Linear functions are used as basic connection methods by a large number of complex networks, such as MLP and Hopfield neural network. When a linear function is used, the output of the basis function is the weighted sum of the input and the threshold [14]; namely,

$$z = \sum_{p=1}^n s_p d_p - \alpha = x^T s - \alpha. \quad (10)$$

2.2.2. Radial Basis Function. The core of the radial basis function is the choice of “distance”; for example,

$$z = \|s - a\|_{L^2} = \sqrt{\sum_{p=1}^n (z_p - d_i)^2}. \quad (11)$$

In the formula, a is the center of the basis function [15] that the selection of the distances would not be limited to the Euclidean distance [16] and alternative paradigms would also be possible. In the radial basis function, the radial basis of the neural network is connected to the basis function of the distance function.

2.3. Common Types of Activation Functions

2.3.1. Sigmoid Function. The Sigmoid function is currently the earliest and most widely used activation function in artificial neural network models. It maps the real number input to the interval $[1, 2]$, the Sigmoid function is a strictly single-increasing smooth function and has asymptotic characteristics [17], and its general form is as follows:

$$\text{Sigmoid}(z) = \frac{1}{1 + z^{-\lambda x}}. \quad (12)$$

In the formula, λ is the gain of the Sigmoid function, which controls the slope of the function curve. The larger λ is, the steeper the monotonic curve is. In addition, the Sigmoid function has good smoothness and continuity. In actual calculations, the Sigmoid function has important properties:

$$l'(m) = l(m)(1 - l(m)). \quad (13)$$

But Sigmoid has a more obvious shortcoming; that is, when the input is large or small, the gradient of the entire neuron processing function is almost zero. Therefore, it is very cautious to initialize the parameters; otherwise, it will make the neural network difficult to learn. Another defect of the Sigmoid function is that its output is not zero mean, which may cause deviations in the processing of the original input data, as shown in Figure 1.

For the Sigmoid function, its two major defects limit his application in this paper, but in the process of its operation, we can find its laws to provide a reference for the method of this paper and effectively improve the efficiency of the method of this paper.

2.3.2. Tanh Function. The tanh function graph [18], as an improvement to the Sigmoid function, has the following form:

$$\tanh(a) = 2\text{Sigmoid}(2a) - 1 = \frac{c^{\lambda x} - c^{-\lambda x}}{c^{\lambda x} + c^{-\lambda x}}. \quad (14)$$

As a single hidden layer feedforward neural network, RBF neural network [19] is special in that it uses radial basis function as the activation function of intermediate nodes, so that the network has the characteristics of simple structure and fast learning convergence and it can approach any nonlinear function. The output layer is a linear combination of neurons in the hidden layer. The so-called radial basis function means that the function value is a symmetric multivariate function about the central point. The simple structure of the RBF network is shown in Figures 2 and 3.

There are many choices of radial basis functions, and the commonly used ones are as follows:

(1) Gauss function:

$$v(x) = a^{x^2/\mu^2}. \quad (15)$$

(2) Reflection Sigmoid function:

$$v(x) = \frac{1}{1 + a^{x^2/\mu^2}}. \quad (16)$$

(3) Inverse multiquadratic function:

$$v(x) = \frac{1}{(x^2 + \mu^2)^{1/2}}. \quad (17)$$

The activation function of the hidden neural unit is a function with local sensitivity [20]. Only when the input vector is close enough to a certain center point (near the center point) in the input space, as shown in Figure 3, the hidden unit will be active and make a meaningful response. The characteristic of this function is that the closer to the center point [21] (the smaller the distance from the center point), the larger the corresponding function value. In other words, this characteristic of the radial basis function determines that it is very sensitive to the processing of local information.

2.4. Calculation of Bearing Pressure. According to the theory of elastoplasticity, the calculation formula of the support pressure in the limit equilibrium zone in front of the work surface is the support pressure in the plastic zone.

$$\mathfrak{F}_s = \eta_v \left\{ \begin{array}{l} 1 + \cos \theta^{dg} \left(1 + \cos \theta \right) \\ 1 - \cos \theta^{en} \left(1 - \cos \theta \right) \end{array} \right\}, \quad (18)$$

where d is the coefficient of friction between layers; θ is the friction angle in the coal body; g is the distance from any point in the plastic zone to the coal wall; and N is the thickness of the coal seam n ; $\sin \theta$ is the self-supporting force of the coal body [22].

Let $\mathfrak{F}_s = WzB$ be the distance between the peak point of abutment pressure and the coal wall be y_1 :

FIGURE 1: Sigmoid function and tanh function.

FIGURE 2: RBF network diagram.

FIGURE 3: RBF function graph.

$$y_1 = \begin{cases} N(1 - \cos \theta) \\ d(1 + \cos \theta) \end{cases} k \begin{pmatrix} WzB(1 - \cos), \\ b_1 \sin \theta(1 + \cos \theta), \end{pmatrix} \quad (19)$$

where W is the stress concentration factor; B is the buried depth of coal seam, n ; and x is the bulk density of the overlying strata, WB/n .

In the above formula, assuming that the internal friction angle θ [23] is a fixed value, it is concluded that y_1 only increases with the increase of the thickness of the coal seam under the same coal seam condition. Therefore, the peak point of the support pressure in front of the working face [24] increases with the height of the mining. The increase in the coal is transferred to the deep part of the coal body.

The expression of the support pressure distribution in the elastic zone is as follows:

$$\mathfrak{F}_x = WzBa_{K\alpha}^{2d}(y_1 - y), \quad (20)$$

where α is the lateral pressure coefficient.

Suppose the range of the elastic zone is v_0 and $v = v_0 + v_1$; then substituting $\mathfrak{F}_x = zB$ into the above formula,

$$v_0 = \frac{3d}{K\alpha} k l H. \quad (21)$$

It can be seen from the above formula that the range v_0 of the supporting pressure in the elastic zone in front of the work face increases with the increase of the mining thickness N , and the two formulas (20) and (21) constitute the distribution form of the supporting pressure in the front of the work face. It is observed that the support pressure within the plastic zone increases as an exponential function until the peak support capacity WzB as the distance from the installed coal wall increases; in the flexible zone, the support pressure decreases as a negative exponential and increases to the original support capacity zB . The support pressure range in front of the working face increases with the increase from the mined thickness.

3. Research on Actual Measurement of Underground Pressure Law of Driving Face in Soft Rock of Coal Mine

3.1. Mine Pressure Observation Plan of Working Face

3.1.1. Layout of Measuring Points. During the 8101 working face, the working face is installed with the KJ653-F2 mine-used intrinsically safe roof pressure wireless monitoring substation online monitoring system to monitor the pressure change of the hydraulic support in real time. Each measuring point is equipped with two left and right channels, the left channel monitors the pressure of the left pillar, and the right channel monitors the pressure of the right pillar. The working resistance monitoring data of the hydraulic support can be transmitted to the ground in real time and stored. It can provide basic data for the study of the mining pressure law of the working face, analyze and summarize the abnormal mining pressure area during the mining of the working face, and provide a basis for the safe mining of the working face. The layout of the mine pressure observation area at the working face is shown in Figure 4.

According to the mine pressure monitoring of Selian No. 1 mine, there are three measurement areas in the 8101 working face, of which 1–35# is the upper measurement area, 40–65# is the middle measurement area, and 70–90# is the lower measurement area. The layout plan of surface measurement points is shown in Table 1.

Due to the different arrangements of measuring points monitored by the comprehensive mining support underground pressure monitoring system during the production period of the working face and the comprehensive measuring point layout in the underground pressure monitoring and analysis, the following supports are selected for the underground pressure analysis: 23#, 25#, 27#, 25#, 29#, 31#, 35#, and 38# brackets.

3.1.2. Online Monitoring System for Mine Pressure. The intrinsically safe substation transmits the received sensor data information to the monitoring master station through the bus. The monitoring master station and multiple intrinsically safe substations form an upper and lower master-slave relationship, and the monitoring master station transmits the data of each inspection through the master. The system is sent to the control room on the well and the receiving host of the production technology department, and the KJ653-F2 mine intrinsically safe roof pressure wireless monitoring substation online monitoring system is used for real-time data monitoring and storage [25–27]. The structure of the online monitoring system is shown in Figure 5.

According to the actual mining conditions given by the mine, relevant monitoring systems are, respectively, equipped for the coal mining face and the two downstream channels, as shown in Figure 6.

According to the actual situation of the 8101 working face support, the difference between the pressure values of the left and right columns of the support is small, and there is

not much difference in the topping of the support, so the pressure value of the left column of the hydraulic support is selected as the criterion value for the pressure. The obtained results are shown in Table 2.

3.2. Research on the Characteristics of the Pressure on the Roof of the Working Face

3.2.1. Features of Upper Pressure on Working Surface. Figure 7 shows the variation curve of the cyclic working resistance of the support at the upper stations 5# and 15# on the working face with the advance of the working face.

It can be seen from Figure 7 that the average step distance of the first pressing on the upper part of the working surface is 32.56 m, and the average step distance of the periodic pressing is 15.23 m. The distance from 17.25 m is not much different.

3.2.2. Compression Characteristics in the Middle of the Working Face. Figure 8 shows the variation curve of the cyclic working resistance of the support at 30# and 45# in the upper station of the working face with the advance of the working face.

It can be seen from Figure 8 that the average step distance of initial incoming pressure and the average step distance of periodic incoming pressure of the measuring station in the middle of the working face are reduced. Compared with the upper measuring station, the maximum working resistance of the support is 37.05 MPa and the average working resistance is 36.26 MPa, which are increased compared with the upper measuring station of the working face. It is consistent with the law that the pressure in the middle of the working face is greater than that at both ends according to the above theoretical analysis.

3.3. Research on Characteristics of Working Face Inclination Pressure and Bearing Characteristics and Adaptability of Supports. When the working face moves 55 m, 110 m, and 155 m away from the open excavation, the weighted distribution of the average working resistance and maximum working resistance time of each station support in the slope direction of the working face is shown in Figure 9. From Figure 9, when the working face is 55 m, 110 m, and 155 m, respectively, the overall trend of the average working resistance and maximum working resistance of the three workstations on the working surface remains unchanged. The average and maximum resistance remain unchanged, and the weighted value of the operation time of the central station support is greater than that of the upper and lower station support on the working face. From the above analysis of the support cycle working resistance, it can be seen that the characteristics of the instrument are basically the same at the upper and lower parts of the working face, and the working resistance of the hydraulic support is distributed along the inclined direction of the working face. The characteristics of the works are that the middle part is greater

FIGURE 4: Layout of the mine pressure observation area of the working face.

TABLE 1: Layout plan of measuring points on working face.

Measuring point number	1#	2#	3#	4#	5#	6#	7#	8#
Bracket number	100#	12#	13#	14#	15#	16#	17#	18#
Measuring point number	40#	42#	43#	54#	55#	56#	67#	68#
Bracket number	21#	22#	23#	24#	35#	36#	37#	38#
Measuring point number	82#	83#	85#	92#	94#	96#	112#	115#
Bracket number	23#	25#	27#	25#	29#	31#	35#	38#
Measuring point number	111#	125#	127#	135#	136#	139#	142#	145#
Bracket number	26#	28#	35#	36#	39#	41#	44#	45#

than the upper and lower parts, and the upper part is slightly greater than the lower part, as shown in Figure 9.

In order to analyze the load-bearing characteristics of the support and its adaptability to the working face, according to the layout of the 8105-1 working face measuring station, the middle brackets of the upper, middle, and lower measuring stations are selected, respectively, namely, the 15# bracket of the upper measuring station, the 55# bracket of the middle measuring station, and the 95# bracket of the lower measuring station, statistical analysis is carried out according to the resistance interval with an interval of 5 MPa. The support load distribution histogram is shown in Figure 10, and the overall setting force and working resistance statistics of the working face are shown in Table 3.

From Figures 9 and 10 and Table 3, we can get the bearing characteristics of the working face support as follows:

- (1) The setting force of the support of the entire working face is approximately normally distributed, the setting force of the 10–30 MPa interval accounts for more than 85% of the total number of statistics, and the setting force of the upper, middle, and lower three stations is 10. The frequency of ≥ 25 MPa is between 55% and 65%. From the foregoing analysis, it can be seen that the setting force of the working face support is generally low due to the impact of the support bottom drilling. Therefore, it is necessary to

standardize support operations and strengthen the management of hydraulic pumping stations and other pieces of equipment, through measures such as timely rehydration to ensure that the setting force of the stent meets the requirements.

- (2) The working resistance of the working face support is mostly distributed in the range of 10–35 MPa, and the distribution of the working resistance is relatively concentrated, approximately in a normal distribution. As a whole, the frequency of the support distributed in the high resistance (>20 MPa) area is greater than the low resistance (<20 MPa). The regional frequency, in the figure, shows that the peak area of the normal curve is biased to the high resistance area on the right, and there is basically no part that exceeds the rated working resistance in the interval greater than 35 MPa, indicating that the overall support effect of the stent is good.

4. Results and Analysis of Mine Pressure Observation

4.1. Monitoring Results and Analysis of the Working Resistance of the Working Face Support. Sort out the actual working resistance of 25 supports (3 #, 13 #, 43 #, 23 #, 85 #, 27 #, 127 #, and 35 #) by left and right columns, and compare the average working resistance, maximum working resistance,

FIGURE 5: The structure of the mine pressure online monitoring system.

whole working resistance, and the average working resistance of left and right columns in each operation cycle of the support.

When 14202 working face is 2 m away from the cut hole, the pressure observation equipment under the mine can be debugged in the fully mechanized mining face. The actual observation time is 70 days in total. When the observation work is completed, the working face has been advanced by 142 M. In addition to the power failure time and equipment failure factors above the mine, the continuous observation of the data information of the support resistance every five minutes has been completed to a certain extent, and the data information is collected manually in the power failure stage. The relevant monitoring results show that the ground pressure observation work can roughly understand the ground pressure presentation law of this working face, which provides a certain basis for scientifically analyzing the actual bearing situation and operation characteristics of relevant

supports in 14202 working face and creating and analyzing the coal seam roof structure. For this working face monitoring system, the data obtained from the monitoring of 13 #, 85 #, 98 #, ..., 127 # supports are processed to obtain the internal law that the actual working resistance of each observed support changes with the change of the actual distance of the working face, as shown in Figure 11.

Before the second compression, the supports at each observation point should work under a controlled force (31.5 MPa). After the interruption of work began, the general trend of the 40 m midprojection stage was to increase steadily, but the change in the support resistance of the observation point was relatively small. This phenomenon shows that before the main roof ruptures for the first time, the moving range of the roof is relatively small, and the resistance of the bracket is also greatly restricted due to the replacement of the roof. Under normal conditions, when the top plate is pressed down, the strain

FIGURE 6: Schematic diagram of part of the underground structure.

TABLE 2: Criterion value of each bracket.

Station distribution	Measuring point number	Bracket no.	Average work resistance	Mean resistance standard deviation	To overwhelm the criterion value
Upper station	1#	5#	18.56	5.24	22.36
	5#	7#	23.58	6.23	25.56
	8#	11#	26.53	6.52	24.89
Central station	15#	50#	26.78	4.25	32.56
	20#	52#	27.23	3.25	33.36
	25#	61#	25.36	5.26	36.58
Lower station	32#	65#	22.13	5.78	27.54
	35#	67#	12.56	6.59	22.41
	37#	72#	18.56	6.87	22.13
	42#	75#	25.56	7.85	20.23

resistance changes significantly. In the actual mining stage, the working resistance between the left and right pillars varies greatly. The actual working resistance of the left and right columns of the support at other positions of the working surface is relatively small, and part of the load is not visible. This shows to a certain extent that the resistance of most of the left and right pillars on the working surface is relatively uniform, some observation points have serious eccentric loads, and the actual force state of the left column is higher than that of the right column. When these supports have long-term severe eccentric load conditions, the application of the roof will increase the pressure on the support of the observation point to a certain extent, which will cause an uneven force of the support. Then, the damage of the hydraulic support means the management of the roof of the working surface. There are certain risks. In order to avoid this phenomenon, it is necessary to balance the distribution of stent resistance.

Factors leading to eccentric load are as follows: during the lifting process, the total amount of liquid injected into the length of the left and right arms of the observation point was not checked correctly, resulting in an imbalance between the left and right pillars of the valve stem. It is caused by leakage in the actual operation stage of the observation point arm. The first is an important factor that causes the eccentric load of the stent. Strictly designing the stent perfusion procedure, especially, the injection should achieve the nominal adjustment force of the stent, and strengthening monitoring and management is an effective way to solve this problem.

4.2. Observation Results and Analysis of Advanced Support along the Groove of the Working Face. Observation sites are set, respectively, in the transportation and return channels of the working face. This is to better observe the advance

FIGURE 7: : 5# and 15# support cycle working resistance changes with the advancement of the working face.

FIGURE 8: 30# and 45# bracket cyclic working resistance changes with the advancement of the working face.

support resistance of the working face. The details are shown in Figure 12.

The observation station adopts a cyclic operation form to complete advanced support resistance monitoring. The monitoring station should be moved to the end of the work surface in each monitoring cycle. According to these observations, during the period of inflow pressure, the rising rate of advance support resistance will increase significantly. Generally speaking, the shorter the distance between the site and the working surface is, the faster the advance support resistance will rise. Therefore, when predicting the working surface pressure, the regular curve that supports the distance between the resistance and the working surface can be completely used. During the observation period, the pressure of the single column was relieved due to the installation of the instrument. The initial measurement pressure was relatively low, but the carriage return and transfer set were in good up and down states, and finally, there was no monitoring that affected the change method. Analyzing the observation results related to the pressure

of road mines, it can be found that the area around the working face becomes a new support point for the rocks on the plate, and the full support pressure can be far away from the coal wall. The analysis of advanced support pressure can prove the emergence of the maximum support pressure, from the actual impact of the support pressure 4–6 meters in front of the bomb wall to 30 cm in front of the work.

4.3. Statistical Observation Results and Analysis of Working Face

4.3.1. Roof Fall in Working Face and Coal Slabs.

According to the statistical observation results, when the working face advances 40 m, 55 m, 80 m, 125 m, and 135 m, the roof will fall on the beam at the upper end of the support platform. The roof fall is generally 3–6 m long and 1–3 m wide. Most of the positions are concentrated on the work and the central part of the face. Under normal conditions, the end of the working face is 0.5–0.75 m wide

FIGURE 9: Distribution map of bracket average working resistance and maximum working resistance time-weighted value at different distances.

FIGURE 10: The histogram of the frequency characteristics of the support setting force distribution at different stations in the working face.

TABLE 3: Distribution of support setting force and working resistance of each station in the working face.

Where the station	Bracket number	Proportion of each resistance/%			
		Setting force		Work resistance	
		<25 MPa	≥25 MPa	<25 MPa	≥25 MPa
Upper part	5#	71.25	28.56	52.56	47.58
	15#	70.26	21.56	54.58	48.56
	25#	72.32	20.23	45.26	49.23
	Average	73.56	19.85	49.26	52.23
Central	45#	71.45	18.25	58.56	51.23
	55#	70.23	20.36	42.23	45.23
	65#	70.69	22.25	52.23	50.23
	Average	80.23	24.56	49.56	48.25
Lower part	85#	82.23	25.56	50.23	51.23
	95#	74.56	26.58	41.23	49.25
	105#	75.65	24.56	49.56	50.2
	Average	78.59	22.23	48.51	49.23

(a)

(b)

FIGURE 11: The average working resistance changes with the advancing distance of the working face. (a) 13# average working resistance changes with the advance distance of the working face. (b) 98# average working resistance changes with the advance distance of the working face.

FIGURE 12: The relationship between the advance support resistance and the distance to the coal wall.

and 0–2.5 m long. When the working face is used, sometimes coal wall slag will appear. Generally, the slag depth is 0.4–0.64 m and the slag length is 1–2.5 m. Generally, sliding and roof falling will occur when pressure is applied during work. When periodic pressure and initial pressure are applied on the roof, serious rock stratum pressure will occur. At the same time, the roof beams of some supports are not easy to contact. It will cause the tunnel and roof to fall.

4.3.2. Suspended Roof behind the Working Face Frame and Sinking of Steps. When the working face moves forward 40 m, 55 m, 80 m, 125 m, and 135 m, the rear suspension phenomenon will occur. The suspension ring is generally located at the upper and lower ends of the working face, and the length behind the frame is 3–6 m. The working face is 38 m–84 m, and the coal wall roof of the working face has cracks. The crack width is 8–17 mm and the length is 5–11 m. However, there is no roof step sinking along the coal wall.

5. Conclusions

In this paper, a series of ground pressure monitoring and surrounding rock control measures and analysis methods are studied, especially for the essential structure and law of rock stratum in the process of short-range coal seam mining, and the differences of corresponding coal seam characteristics in short-range are explained in detail. Combined with the deformation law of surrounding rock in the working face, more appropriate support methods and parameters are obtained. And the size design method is generated, which lays a better foundation for efficient, safe, and reliable mining in the subsequent mining area. This paper systematically expounds the ground pressure observation and result analysis of coal mine 7706 working face. Firstly, combined with the engineering geological conditions of the 7706 working face in Datun coal mine of China coal mine, the ground pressure observation scheme is designed, and one observation station is established between 15 holders in the working face, so the total number of observation stations is 5, and the number of survey lines is 5 and 1 to facilitate measurement. Then, the characteristics of the first pressure on the working face are deeply analyzed, including the determination method of the judgment basis of the first pressure on the working face, the judgment method of the first pressure step, and the judgment method of the first pressure strength. Next, the detailed characteristics of periodic pressure on the working face are analyzed, mainly including the interpretation basis of periodic pressure on the roof, the judgment of periodic pressure on the roof, the statistical analysis of periodic pressure step, the strength of periodic pressure, and the characteristics of roof pressure on different parts. Finally, the distribution and influence of advance support pressure in stope are deeply analyzed, including the determination of the distribution range of advance support pressure and the influence of advance support pressure on roof deformation.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors state that they have no conflicts of interest.

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