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Research Article

A New Method to Predict Shock-Type Coal-Gas Outburst Disaster and Its Application

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Coal-gas outburst is the one of most serious coal mine dynamic disasters which affects safety mining, with 39 deaths reported during 2019 in China. The mechanism of coal-gas outbursts is complex, and the prediction methods are immature at present. This article was based on previous research results. Firstly, the occurrence mechanism of coal-gas outburst disasters was summarized. It is clear that the occurrence of coal-gas outburst disasters is jointly affected based on the stability of the static structure of coal-rock, the gas parameters, and the release intensity of shock stress. Secondly, the stability evaluation models of coal-rock static structure, gas parameters, and shock stress release intensity were built, respectively, based on the influence factors. Then they were coupled and supposed to form a new prediction model. Finally, the prediction method was applied to the Ji_{15}-17200 working face of No.12 coal mine in Pingmei company. The working face was divided into three danger levels including weak outburst danger area, medium outburst danger area, and strong outburst danger area. The accuracy of the predicted results was analyzed based on the actual mining condition of the Ji_{15}-17200 working face. The results show that prediction accuracy is high, and it can be used for actual applications. The research results are of guiding significance to better prevent and control coal-gas outburst accidents and ensure safe production in coal mines.

1. Introduction

Coal is the main source of energy in China. With the yearly increase of coal mining depth, the coal seam gas pressure and the in situ stress are also increasing, and the danger of mine dynamic disaster is increasing especially coal-gas outburst [1–6]. At present, the requirements of coal precision and intelligent mining pose more difficult challenges to the effective prevention and control of dynamic disasters such as coal-gas outburst [7–15]. Therefore, it is imperative to research coal-gas outburst prediction methods with high accuracy and suitable for engineering applications.

Domestic and foreign scholars have carried out a lot of research results on coal-gas outburst predictions, forming a series of commonly used coal-gas outburst danger prediction technology, such as drilling cuttings method [16], drilling gas inrush initial velocity method [17], etc. Meanwhile, geophysical methods have been gradually applied to coal-gas outburst prediction in recent years, such as the acoustic emission method [18], microseismic method [19], and electromagnetic radiation method [20]. In addition, according to the time series feature of coal-gas outburst, prediction indexes can be divided into dynamic prediction and static prediction, and critical value was often used to judge the danger of coal-gas outburst in static prediction; for dynamic prediction, the method based on the change characteristics of precursory information of monitoring indexes was used to determine the danger of coal-gas outburst. Lama and Bodziony [21] studied coal-gas outburst risk prediction technology and prevention and control measures based on management system, decision-making, and risk analysis; safety mining process of outburst coal seam was put forward. Cyrul [22] used data mining technology to study the prediction method of outburst coal seam in Poland and has got good application results. The development of data mining technology provides more theoretical support for the prediction of coal-gas outburst danger, such as the neural network method [23], fuzzy comprehensive evaluation [24], gray theory method [25], and extreme learning machine method [26]. Song and Zhang [27, 28] predicted and visualized the coal-gas outburst area based on geographical information system technology. Zhang et al. [29–31] studied a new prediction method of coal-gas outburst based on the η parameter that was put forward on the basis of experimental study, and its dangerous level was divided into five categories; the method was compared with other traditional methods at the same time. Liu et al.'s physical simulation system for large coal-gas outburst had been developed, and the occurrence mechanism of coal-gas outburst was analyzed from the perspective of energy, which laid a theoretical foundation for the accurate prediction of coal-gas outburst disasters.

Some typical coal-gas outburst prediction methods were listed above, and most of them use precursor information or data mining technology to judge the possibility of outburst, few studies on constructing prediction criteria of outburst disasters from the perspective of outburst disaster mechanism. In this article, we first elaborated the coal-gas outburst disaster occurrence principle, and the prediction method was constructed based on the outburst principle; finally, the instance prediction and effect test are carried out, and a new prediction method of coal-gas outburst disaster is formed; it provides new approaches for the accurate prediction of such disasters.

2. Shock-Type Coal-Gas Outburst Occurrence Principle

According to relevant theories [32, 33], as shown in Figure 1, the stress source of shock-type coal-gas outburst disaster includes static stress of coal-rock, dynamic load stress induced by mining, and gas pressure in cracks of coal-rock. Higher static stress of coal-rock near mining working face, the corresponding gas pressure, and ultimate strength are low. The mechanism of coal-gas outburst is in the final analysis that the combined load of coal-rock exceeds its bearing strength and destroys. When mining induced dynamic load superimposed to the adjacent working face area and meets the critical load of coal-rock dynamic disaster that will induce coal-gas outburst disaster; the stress formula is shown in

$$\sigma_s + \sigma_d + \sigma_g \geq \sigma_{b\ min}, \quad (1)$$

where σ_s is the static load stress of coal-rock, σ_d is the dynamic load stress induced by mining, σ_g is the gas pressure in fissure of coal-rock, and $\sigma_{b\ min}$ is the critical load of coal-gas outburst.

It can be known that when the sum of static load, dynamic load, and gas pressure exceeds the critical load of dynamic disaster, the dynamic disaster will occur, as shown in Figure 2. Therefore, it is considered that the prediction of shock-type stress release coal-gas outburst disaster should be carried out from three aspects: stability of static excavation structure of coal-rock, gas parametric strength, and shock-type stress release strength.

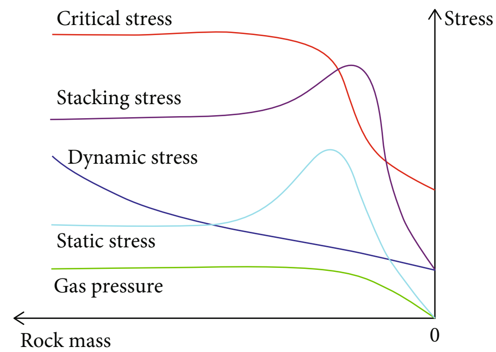

Figure 1: Critical condition of shock-type coal and gas outburst disaster.

3. New Method to Predict Shock-Type Coal-Gas Outburst

3.1. Evaluation of Static Structure Stability. The complex coal-gas outburst coal-rock structures are formed by the geological conditions in the coal mining area and the underground mining activities. The coal-rock structures of shock-type coal-gas outburst are mainly controlled by the coupling of geological conditions and mining activities. Geological conditions mainly include coal seam and roof-floor lithologic characters and geological structure. After roadway excavation or working face mining, coal-rock might form a permanent or temporary static structure. When the coal-rock structure is disturbed by external vibration, it is easy to cause sudden stress distribution imbalance, to trigger instability of coal-rock structure, and combined with gas pressure effect, the shock-type stress release coal-gas outburst disaster occurs. Therefore, the prediction method of coal-gas outburst based on shock-type stress release includes four aspects: static coal-rock structure stability evaluation technology, gas parameter strength evaluation technology, working face disturbance strength evaluation technology, and classification prediction criterion establishment. The detailed description is as follows. The evaluation indexes of coal-rock static structure stability mainly include mining depth, ground stress level, coal-rock properties, geological structure, and change of coal seam thickness.

3.1.1. Mining Depth. The mining depth of coal seam is an important index for predicting coal-gas outburst disasters and evaluating the static structure of coal-rock. According to the analysis of mining depth and the latest comprehensive index method [34, 35], the mining depth index is defined to evaluate the stability of the static structure of coal-rock as follows: when H (the mining depth) > 1000 m, the stability index of the static structure of coal-rock is 4; when $700 < H \leq 1000$ m, the stability index of coal-rock static structure is 3; when $400 < H \leq 700$ m, the stability index of coal-rock static structure is 2; when $H \leq 400$ m, the stability index of coal-rock static structure is 1.

3.1.2. In Situ Stress. Coal-gas outburst is a dynamic phenomenon of rapid release of stress and energy. Therefore, the in

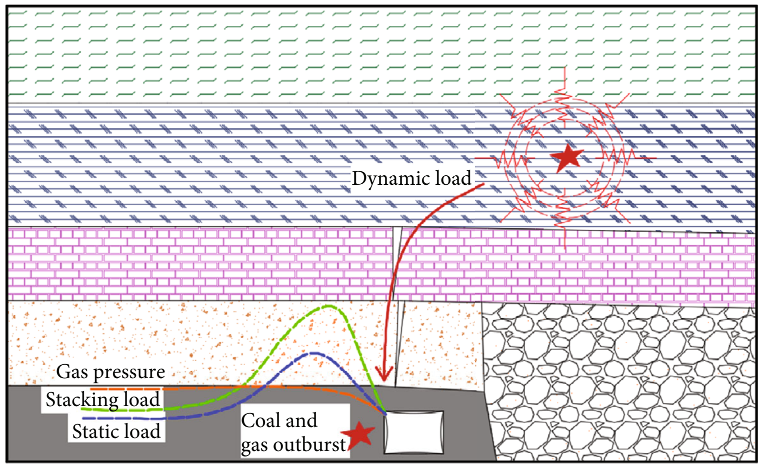

FIGURE 2: Model of shock-type coal and gas outburst disaster.

situ stress of coal mining area is an important index to evaluate the static structure of coal-rock. The in situ stress evaluation used in this paper includes two indexes of original rock stress and mining stress, maximum principal stress index is used in original rock stress, and stress concentration coefficient index is used in mining stress. When the maximum principal stress $\sigma_1 > 30$ MPa, the static structural stability index of coal-rock is 4; when $24 < \sigma_1 \leq 30$ MPa, the stability index of static structure of coal-rock is 3; when $18 < \sigma_1 \leq 24$ MPa, the stability index of static structure of coal-rock is 2; when σ_1 is less than 18 MPa, the stability index of the static structure of coal-rock is 1. When the stress concentration factor $k > 2.8$, the static structure stability index of coal-rock is 4; when $2.3 < k \leq 2.8$, the stability index of static structure of coal-rock is 3; when $1.7 < k \leq 2.3$, the stability index of coal-rock static structure is 2; when $k \leq 1.7$, the stability index of the static structure of coal-rock is 1.

3.1.3. Coal-Rock Mass Attribute. Coal-gas outburst and static structure formation are also controlled by coal-rock properties. The index evaluation of the impact tendency of coal seam and roof is adopted. The static structural stability index of coal-rock corresponding to strong impact tendency of coal seam and roof is 4, the static structural stability index of coal-rock corresponding to medium impact tendency of coal seam and roof is 3, the coal-rock static structural stability index corresponding to the weak impact tendency of coal seam and roof is 2, and the static structural stability index of coal-rock corresponding to nonimpact tendency of coal seam and roof is 1.

3.1.4. Geological Structure. Coal mining in geological structure area and nongeological structure area has great difference in forming static structure of coal-rock, because geological structure is difficult to quantify, so according to the geological structure, severity is strong, general, weak, and no geological structure classification; the corresponding static structural stability indexes of coal-rock are 4, 3, 2, and 1, respectively.

3.1.5. Variation of Coal Seam Thickness. The practice shows that the stability of regional coal-rock structure is poor when the coal thickness changes sharply. And coal-gas outbursts occur frequently, which may be due to unbalanced stress transfer. The change degree of coal thickness is summarized into four categories: severe change, relatively severe change, stable change, and almost no change; the corresponding static structural stability indexes of coal-rock are 4, 3, 2, and 1, respectively.

Based on the above coal static structure stability evaluation index and index determination, evaluation results of static structural stability of coal-rock *Sta* are shown in

$$Sta = \frac{S_1 + S_2 + L + S_n}{n}, \quad (2)$$

where S_1, S_2, and S_n are the indexes of n indexes for evaluating stability of coal-rock static structure.

3.2. Evaluation of Gas Parameters. The gas parameter strength of working face is mainly controlled by gas pressure, gas content, absolute gas emission rate, and initial velocity of gas release.

3.2.1. Gas Pressure. Original gas pressure in coal seam is the key factor of coal-gas outburst disaster. The normal case, multipoint gas pressure measurement in working face of coal-gas outburst mine. But in general case, the part of gas pressure parameters in the prediction unit can be collected. The remaining uncollected unit grid gas pressure parameters are calculated by interpolation method, calculation method of interpolation method without detailed description. Dividing gas pressure into four grades is as follows: when the gas pressure is $P \leq 0.2$ MPa, the corresponding gas reflection strength index is 1; when the gas pressure is $0.2 < P \leq 0.4$ MPa, the corresponding gas reflection strength index is 2; when the gas pressure is $0.4 < P \leq 0.74$ MPa, the corresponding gas reflection strength index is 3; when the gas pressure is $P > 0.74$ MPa, the corresponding gas reflection strength index is 4.

Table 1: Disturbance intensity index of shock-type coal and gas outburst by hard roof.

Serial number	Thickness, m	Compressive strength, MPa	Distance between hard rock and coal seam, m	Disturbance intensity index
1	≥30	≥60	<20	6
2	15~30	≥60	<20	5
3	<15	≥60	<20	4
4	≥30	≥60	20~40	5
5	15~30	≥60	20~40	4
6	<15	≥60	20~40	3
7	≥30	≥60	≥40	4
8	15~30	≥60	≥40	3
9	<15	≥60	≥40	2
10	≥30	35~60	<20	5
11	15~30	35~60	<20	4
12	<15	35~60	<20	3
13	≥30	35~60	20~40	4
14	15~30	35~60	20~40	3
15	<15	35~60	20~40	2
16	≥30	35~60	≥40	3
17	15~30	35~60	≥40	2
18	<15	35~60	≥40	1

3.2.2. Gas Content. Coal seam gas content is also the key factor of coal-gas outburst disaster. The normal case multipoint gas pressure measurement in working face of coal-gas outburst mine, but general case the part of gas pressure parameters in the prediction unit can be collected, the remaining uncollected unit grid gas pressure parameters are calculated by interpolation method, calculation method of interpolation method without detailed description. Dividing gas content into four grades is as follows: when the gas content is $Q \leq 5\,\mathrm{m^3/t}$, the corresponding gas reflection strength index is 1; when the gas content is $5 < Q \leq 12\,\mathrm{m^3/t}$, the corresponding gas reflection strength index is 2; when the gas content is $12 < Q \leq 20$ $\mathrm{m^3/t}$, the corresponding gas reflection strength index is 3; when the gas content is $Q > 20\,\mathrm{m^3/t}$, the corresponding gas reflection strength index is 4.

3.2.3. Absolute Gas Emission Rate. Absolute gas emission rate has a great effect on coal-gas outburst disaster. If the absolute gas emission is not measured in the predicted grid unit, the interpolation method is also used for calculation. Dividing absolute gas emission rate into three grades is as follows: when the absolute gas emission rate is $U \leq 10\,\mathrm{m^3/min}$, the corresponding reflection strength of gas parameters is 1; when the absolute gas emission rate is $10 < U \leq 30\,\mathrm{m^3/min}$, the corresponding reflection strength of gas parameters is 2; when the absolute gas emission rate is $U > 30\,\mathrm{m^3/min}$, the corresponding reflection strength of gas parameters is 3.

3.2.4. Initial Velocity of Gas Release. Initial velocity of gas release is also an important index of coal-gas outburst disaster. Interpolation method is also used to predict weak grid cell without this index. Dividing absolute gas emission rate into three grades is as follows: when the absolute gas emission rate is $q \leq 2.5\,\mathrm{L/min}$, the corresponding reflection strength of gas parameters is 1; when the absolute gas emission rate is $2.5 < q \leq 4.5\,\mathrm{L/min}$, the corresponding reflection strength of gas parameters is 2; when the absolute gas emission rate is $q > 4.5\,\mathrm{L/min}$, the corresponding reflection strength of gas parameters is 3.

Table 2: Static structure calculation process of coal and rock.

	S_1	S_2	S_3	S_4	S_5	S_6	*Sta*
1	2	4	1	2	1	1	1.83
2	2	4	1	2	1	1	1.83
3	2	4	1	2	1	1	1.83
4	2	4	1	2	1	1	1.83
5	2	4	1	2	1	1	1.83
6	2	4	1	2	1	1	1.83
7	2	4	1	2	1	1	1.83
8	2	4	1	2	1	1	1.83
9	2	4	2	2	1	1	2
10	2	4	2	2	1	1	2

Based on the above gas parameter strength evaluation index and index determination, the gas parameter strength evaluation result *Sta* is shown in

$$Gas = \frac{G_1 + G_2 + L + G_n}{n}, \tag{3}$$

where G_1, G_2, and G_n are the indexes of n indicators for evaluating the static structural stability of coal-rock.

3.3. Evaluation of Vibration Stress Release Intensity. The disturbance strength of working face is mainly affected based on the mining thickness of coal seam, degree of fault activation, stability of residual coal pillar, and activity strength of hard roof and the filling degree.

3.3.1. Coal Seam Thickness. The thickness of coal seam in working face has great influence on roof caving and its shock disturbance. Therefore, the mining thickness of coal seam is regarded as an important index to evaluate the disturbance strength of coal-rock. According to field observation and practical experience, when the coal seam mining thickness $h > 6\,\mathrm{m}$ was drafted, the coal-rock disturbance strength index was 4; when $4 < H \leq 6\,\mathrm{m}$, the coal-rock disturbance strength index was 3; when $2 < H \leq 4\,\mathrm{m}$, the coal-rock disturbance strength index was 2; when $H \leq 2\,\mathrm{m}$, the coal-rock disturbance strength index was 1.

3.3.2. Fault Activation Degree. Working face mining results in the activation of faults near the face. The fault activation would easily induce high energy shock disturbance near the working face. According to relevant research results [36] judge the disturbance strength index of the fault to the shock-type stress release coal-gas outburst. When the

Table 3: Gas parameter strength calculation process.

	G_1	G_2	G_3	G_4	*Gas*
1	3	2	1	2	2
2	3	2	1	2	2
3	3	2	1	2	2
4	3	2	1	2	2
5	3	2	1	3	2.25
6	3	2	1	3	2.25
7	2	1	1	3	1.75
8	2	1	1	3	1.75
9	2	1	1	3	1.75
10	2	1	1	3	1.75

Table 4: Disturbance strength calculation process.

	D_1	D_2	D_3	D_4	D_5	D_6	*Dis*
1	3	0	3	2	5	2	2.5
2	3	0	3	2	5	2	2.5
3	3	0	3	2	5	2	2.5
4	3	0	3	2	5	2	2.5
5	3	0	3	2	5	2	2.5
6	3	0	3	2	5	2	2.5
7	3	0	3	2	5	2	2.5
8	3	0	3	2	5	2	2.5
9	3	0	3	2	5	2	2.5
10	3	0	3	2	5	2	2.5

coal wall is 62~39 m away from the fault, the coal-rock disturbance strength index is 2; when the coal wall is 40~18 m away from the fault, the coal-rock disturbance strength index is 3; when the coal wall is 18~0 m away from the fault, the coal-rock disturbance strength index is 4; when the coal wall crosses the fault 0~40 m, the coal-rock disturbance strength index is 2; when the coal wall crosses the fault 40~80 m, the disturbance strength index is 1.

3.3.3. Mining Speed. Mining speed is also a key factor affecting the occurrence of high energy shock. The increase of mining speed will induce the violent activity of roof, and the frequency and energy of mine earthquakes will increase. According to the corresponding relationship between mining speed and the occurrence of high energy mine earthquake, the disturbance strength index of shock-type stress release coal-gas outburst caused based on proposed mining speed is as follows: when the mining speed is greater than 6 m/d, the coal-rock disturbance strength index is 4; when the mining speed is 4~6 m/d, the coal-rock disturbance intensity index is 3; when the mining speed is 2~4 m/d, the coal-rock disturbance strength index is 2; when the mining speed is less than 2 m/d, the coal-rock disturbance strength index is 1.

3.3.4. Residual Coal Pillar Stability. Coal mining in working face, the residual coal pillars near the working face for various reasons. The residual coal pillar causes higher degree of stress concentration. Therefore, the index of disturbance strength of shock-type stress release coal-gas outburst caused based on the coal pillar size is proposed. When the coal pillar width is greater than 80 m, the coal-rock disturbance strength index is 1; when the coal pillar width is 60~80 m, the disturbance strength index is 2; when the coal pillar width is 40~60 m, the disturbance strength index is 3; when the coal pillar width is 20~40 m, the disturbance strength index is 4; when the coal pillar width is 10~20 m, the disturbance strength index is 3, when the coal pillar width is 0~10 m, the disturbance strength index is 2.

Table 5: Coal and gas outburst risk index.

	Sta	*Gas*	*DIS*	ODI
1	1.83	2	2.5	6.33
2	1.83	2	2.5	6.33
3	1.83	2	2.5	6.33
4	1.83	2	2.5	6.33
5	1.83	2.25	2.5	6.58
6	1.83	2.25	2.5	6.58
7	1.83	1.75	2.5	6.08
8	1.83	1.75	2.5	6.08
9	2	1.75	2.5	6.25
10	2	1.75	2.5	6.25

3.3.5. Hard Roof Activity Strength. The fracture of hard roof is another key factor to induce high energy shock. But the disturbance effect of hard roof is the result of three indexes including the distance between hard rock and coal seam. The thickness of hard rock and the compressive strength of hard rock. The disturbance intensity index caused by the comprehensive effects of the three indexes is shown in Table 1.

3.3.6. Goaf Filling Degree. After the working face is mined, the roof caving above the gob with different conditions will occur to different degrees. The disturbance strength exerted on the static structure of coal-rock based on different degrees of caving is bound to be different. The filling degree of gob after roof caving is divided into four categories: complete filling, basic filling, few filling, and basically no filling; the corresponding coal-rock disturbance strength index is 1, 2, 3, and 4, respectively.

Based on the above shock-type stress release coal-gas outburst disturbance strength index and index determination, the disturbance strength index evaluation result *Dis* is shown in

$$Dis = \frac{D_1 + D_2 + L + D_m}{m}, \tag{4}$$

where D_1, D_2, and D_n are the indexes of m indicators for disturbance intensity evaluation.

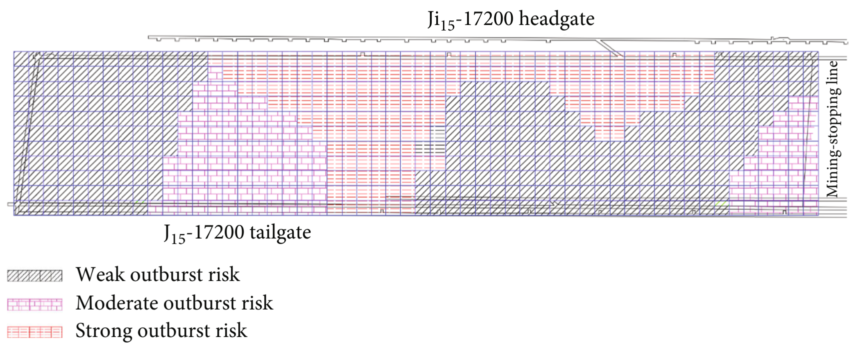

Figure 3: The classification prediction result of coal and gas outburst risk of the Ji_{15}-17200 working face.

3.4. Prediction Criterion. According to the above analysis results, the static structural stability of coal-rock, the strength of gas parameters, and the strength of coal-rock disturbance in a certain area of working face can be dynamically evaluated; the superposition of the three evaluation results can constitute the danger evaluation index ODI of shock-type stress release coal-gas outburst, namely:

$$ODI = Sta + Gas + Dis. \quad (5)$$

The criteria for classification of prominent risk levels are defined as follows: when ODI is <2.8, for no outstanding danger; when $2.8 \le \text{ODI} < 5.0$, for weak outburst danger; when $5.0 \le \text{ODI} < 7.2$, for moderate outburst danger; when $7.2 \le \text{ODI}$, for strong protruding danger.

Shock-type stress release coal-gas outburst danger classification prediction process is as follows:

(1) The prediction area is divided into 5 m, 10 m, or 20 m grid cells as required

(2) According to the actual situation, the coal-rock static structure stability index, gas parameter strength index, and disturbance strength index are filled in each grid unit

(3) The *Sta* index, *Gas* index, and *Dis* index in each grid cell were calculated, and then the shock-type stress release coal-gas outburst danger index ODI was calculated

(4) Classification of outburst hazards based on calculation results, complete classification prediction of coal-gas outburst

4. Engineering Application and Its Validation

4.1. Basic Information of Coal Face. The No.12 coal mine of Pingmei company is a typical coal and gas outburst mine in Henan, China, which is south adjacent gob of the working face Ji_{15}-17200, untapped areas in the north, east adjacent to downhill, west adjacent well field boundary. The ground elevation of the working face is +170~+220 m, elevation of working face -483 m~-574 m. The average dip angle is 19°, the inclination length is 225.3 m, the strike length 762.5 m, the coal seam thickness 2.2~3.7 m, the gas content 15.256 m^3/t, the gas pressure 1.5 MPa, the relative gas emission 7.8~11.9 m^3/t, and the absolute gas emission rate 4.47~8.8 m^3/min. Siltstone with thickness of 2.45~4.11 m and 0.76~1.95 m at direct top and bottom, respectively, the basic roof is medium sandstone with a thickness of 11.51~16.82 m, the basic bottom is 7.83~11.52 m flour fine sandstone. A total of 7 typical faults were exposed in the tunneling process of transportation and return air along the working face; faults are FD35 ($H = 0 \sim 8$ m), FD36 ($H = 0 \sim 10$ m), LF10 ($H = 1.1$ m), LF11 ($H = 2.5$ m), LF12 ($H = 3.0$ m), LF13 ($H = 1.9$ m), and LF14 ($H = 2.6$ m).

4.2. Prediction Results and Its Analysis. Based on the above prediction method of coal-gas outburst disaster, combined with the actual geological condition of the Ji_{15}-17200 working face in the No.12 coal mine in Pingmei company. And the risk of coal and gas outburst during the working face mining is classified and predicted. Firstly, the Ji_{15}-17200 working face was divided into a square grid with a side length of 20 m. Secondly, the parameter data from each grid was collected on site. Thirdly, the static structural stability index of coal-rock in each grid was calculated, respectively, as gas parameter strength index and disturbance strength index. Then the coal-gas outburst danger index of each grid was calculated according to the prediction criterion. Because of the large amount of data, only some grid data are enumerated in the calculation process, as shown in Tables 2–5. In Table 2, $S_1 \sim S_6$ represent the indexes which affect the static structure of coal-rock, respectively, which are coal seam mining depth, maximum principal stress, stress concentration coefficient, coal seam impact tendency, geological structure strength degree, and coal thickness change degree. In Table 3, $G_1 \sim G_4$ represents gas pressure, gas content, absolute gas emission rate, and initial velocity of gas release. In Table 4, $D_1 \sim D_6$ represent the indexes that affect the disturbance strength of coal-rock, respectively, which are the thickness of coal seam once stopping, degree of fault activation, mining speed, remaining coal pillar, hard roof, and filling degree of gob. Figure 3 is the classification prediction results of coal-gas outburst danger in the Ji_{15}-17200 working face of No.12 coal mine in Pingmei company. Comparing the prediction results with coal-gas outburst in actual mining, serious crown drill occurred when mining to strong outburst danger area during mining of the Ji_{15}-17200 working face, and drill cuttings increased significantly compared with other areas. The possibility of coal-gas outbursts has greatly increased. It shows that the prediction result has a certain accuracy, and it can be used for field practical applications.

5. Conclusions

Based on the principle of coal-gas outburst occurrence, a new prediction method of coal-gas outburst disaster was developed and has been applied on the No.12 coal mine in Pingmei company, China. The actual application effects were well. The main conclusions are as follows:

(1) The principle of shock-type coal-gas outburst disaster was expounded. It was considered that the prediction of shock-type coal-gas outburst disasters should be considered from three aspects: static structure of coal-rock, gas parametric strength, and disturbance strength.

(2) The prediction of shock-type coal-gas outburst was divided into three aspects: static structure evaluation of coal-rock, gas parameter strength evaluation, and disturbance strength evaluation. The corresponding evaluation criteria were constructed, respectively. Finally, the prediction criterion of shock-type stress release coal-gas outburst was proposed

(3) Based on the shock-type coal-gas outburst prediction method, the actual prediction was carried out in the Ji_{15}–17200 working face of the No.12 coal mine in Pingmei company, China. The prediction results were verified and analyzed; the results show that the prediction method has good accuracy and can be popularized and applied

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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