

Research Article

Study on Rock Burst Early Warning in the Working Face of Deep Coal Mines Based on the Law of Gas Emission

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This study is aimed at predicting rock burst disasters in high gas mines. First, the distribution law and correlation of gas and stress in the F₁₅₋₁₇-11111 working face of Pingdingshan No. 13 Mine were analyzed based on the coupling relationship between gas emission and stress in the working face. Next, the relationship between gas emission and stress distribution was revealed, and an early warning method of rock burst in the deep mine working face based on the law of gas emission was proposed and applied to the F₁₅₋₁₇-11111 working face. Finally, the critical value of the gas concentration indicator for rock burst early warning in the F₁₅₋₁₇-11111 working face was determined as 0.05%. The following research results were obtained. The gas emission and the mining stress in the F₁₅₋₁₇-11111 working face are negatively correlated. Mechanically, their correlation satisfies the typical coupling. Besides, the critical value of the gas concentration indicator determined by the proposed early warning method boasts high accuracy in predicting rock burst disasters. It can be used as an early warning method for underground rock burst disasters to promote the safety of working face mining. The research results provide reference and guidance for the monitoring and early warning of rock burst disasters in deep high gas mines.

1. Introduction

Rock burst [1] is a dynamic phenomenon in which the elastic energy accumulated in coal rock is released in a sudden, rapid, and violent way when the mechanical system of coal rock reaches its strength limit, scattering coal rock over roadways with great impact. This disaster, usually accompanied by huge vibration, will damage the roadway and equipment and causes casualties. Scholars at home and abroad have conducted extensive researches on the occurrence mechanism and monitoring and early warning methods of rock burst. A series of rock burst monitoring and early warning techniques have been proposed, including the microseismic method, the electromagnetic radiation method, the stress online method, the acoustic emission method, and the drilling cuttings method. However, these techniques cannot achieve early warning. When the

monitoring indicators reach the danger value, the rock burst disaster is about to occur, failing to leave sufficient time for pressure relief and disaster prevention. Besides, precursor information is needed to determine the risk of rock burst, which is of great inconvenience to the monitoring and prevention of rock burst in mines. At the same time, as the depth and extent of coal mining increase, the gas content and gas pressure in coal seams tend to increase, and the number of deep high gas mines is on the rise. Rock burst disasters occurred in many mines with high gas coal seams in China, such as Laohutai Coal Mine in Fushun, Wulong Coal Mine and Wangying Coal Mine in Fuxin, Tao'er Coal Mine in Handan, Jianxin Coal Mine in Fengcheng, and Pingdingshan No. 10 and 12 Mines [2–4]. The high gas in coal seams complicates the occurrence mechanism of rock burst, which poses a great obstacle to the monitoring and prevention of dynamic hazards in high gas coal seams. Therefore, special

studies on dynamic hazards in high gas coal seams are needed.

Scholars all over the world have done abundant studies on the occurrence mechanism and monitoring and early warning methods of rock burst in high gas mines. Petukhov [5], a scholar from former Soviet Union, was the first to research the combination of rock burst and gas outburst in 1987. Zhang et al. [6–8] were the first to analyze gas-induced coal instability and established a mathematical model of rock burst in gas-bearing coal seams. With the aid of microseisms, gas monitoring, and on-site investigation, Li et al. [9, 10] detected unusual gas emissions before, during, and after rock burst disasters, thus questioning the former idea that rock burst was a kind of coal outburst free from the impact of gas. They held that rock burst in deep mining was closely related to gas; high-pressure gas was highly likely to be involved in the occurrence of rock burst; and there was a kind of rock burst induced by the coupling between mining-induced stress relief and high-pressure adsorbed gas desorption and expansion in gas-bearing porous media and gas storage structures. Dong et al. [11] analyzed the influence of gas on the mechanical properties of coal and the law of gas seepage and fracture expansion and explored the conditions under which rock burst and gas outburst mutually converted in different stages. Yin et al. [12] studied the influence of stress field on gas field and established a gas-solid coupling model. Lu et al. [13] investigated the mechanism of rock burst occurrence in high gas coal seams. Zhang et al. [14] studied the coupling effect between the stress field and the gas field. Yuan et al. [15] summarized the characteristics and mechanism of rock burst in high gas coal seams and analyzed the problems in their study. Stanislaw [16] analyzed the effect of rock-burst-induced ore vibration on gas adsorption from multiple perspectives and factors and discussed the causes and conditions of emissions. Huo et al. [17, 18] proposed a solid-fluid coupling instability theory for coal and gas outburst based on the mechanism of coal rock deformation and gas seepage and established the intrinsic structure relationship of gas-bearing coal. Meanwhile, they proposed a method to determine material parameters. Shane and Tang [19] questioned whether rock burst induced gas, or gas induced rock burst, or both, based on the increase in gas concentration before, during, and after rock burst disasters. Ogieglo et al. [20] studied the effect of mine vibration on gas concentration. Zhou et al. [21, 22] established a one-dimensional flow model for coal and gas outburst, gave a crushing initiation criterion, and discussed the outburst process. Besides, they also studied large-scale outbursts corresponding to constant steady advancement and analyzed the important dimensionless parameters of coal and gas outburst, as well as the criterion. Wang et al. [23] probed into the unified mechanism of rock burst and outburst, explored the influences of coal burst proneness, pore gas pressure, and surrounding rock stress on outburst, and proposed a mathematical model of outburst. Wang et al. [24] researched the influence of gas during the implementation of the drill cuttings method in gas-bearing coal seams and used the classical theory to derive an index of the amount of drill cuttings for detecting rock burst in gas-bearing coal seams.

Liu et al. [25] put forward AVO technology (i.e., amplitude variation with offset) early warning theory of coal seam gas enrichment based on the comparison results of coal seam gas and conventional sandstone gas occurrence mechanism. Zhou et al. [26] analyzed the relationship between energy gathering and energy dissipation during uniaxial compression and cyclic loading of coal samples in different gas pressure environments and concluded that the gas shall be taken into account for burst proneness evaluation in deep mining of high gas mines.

The above studies mainly explain the mechanism behind the occurrence of rock burst in high gas coal seams and the effect of gas on rock burst. The results of these studies conduce to correcting the early warning indicators of the conventional rock burst monitoring technique to make it more applicable to the monitoring and early warning of high gas coal seams. However, methods for early warning of rock burst remain to be found. In this paper, the F₁₅₋₁₇-11111 working face of Pingdingshan No. 13 Mine was taken as the research background. First, the correlation between gas emission and rock burst was studied. Furthermore, a monitoring and early warning method of rock burst in the deep mine working face based on the law gas emission was proposed by using gas monitoring means. In this way, early warning of rock burst was achieved. Finally, the method was applied to engineering practice for verification. The research is expected to provide reference and guidance for the monitoring and early warning of rock burst disasters in deep high gas coal seams.

2. Study Area

2.1. Geological Conditions of Mines. Pingdingshan No. 13 Mine, with a design capacity of 1.80 Mt/a, is developed using double vertical shafts, two levels, rise and dip combined mining. The main minable seam is the lower F coal of the Shanxi Formation, and the main mining coal seam is the F₁₅₋₁₇ coal seam whose average thickness is 5.85 m. The mine field is located on the common flank of Likou syncline and Xiangjia anticline of the Pingdingshan coalfield, with the northeast oriented Gouli normal fault on the southeastern boundary, the coal outcrop near the Xiangjia fault on the northeastern boundary, and the northwest oriented Xingguosi normal fault on the western part. Overall, the strata strike and dip are NW 305°–340° and SW 215°–250°, respectively, and the dip angle is 10°–35°. The northeastern boundary of the mine field is close to the Xiangjia anticline axis, so it is significantly influenced by the Xiangjia anticline structure as a whole. The northwestern part of the mine field is a monoclinic structure that dips to the southwest, and it is accompanied by faults. Due to the Lingwushan syncline, the Baishishan anticline, and the secondary folds and faults perpendicular to the Lingwu syncline, the south-eastern part of the mine field is a complex structural area centered on the Lingwu syncline.

Pingdingshan No. 13 Mine is identified as a gas outburst mine. The distribution of gas occurrence in coal mine shows zonation. The gas content of the coal seam rises as the burial depth increases, and it increases from the west to the east,

resulting in a low gas concentration in the west and a high gas concentration in the east. Nevertheless, the gas concentration may vary locally due to the influence of faults, folds, and magmatic rocks. In the eastern part of the mine field, the gas contents of the F_1 and F_3 mining areas are the highest, with the measured maximum gas content at an elevation of -720 m being $16.09 \text{ m}^3/\text{t}$. All the three dynamic disasters that once threatened the mine occurred in the two mining areas. The gas content of the F_4 mining area in the western part of the mine field is relatively low, the measured maximum gas content at an elevation of -660 m being $10.28 \text{ m}^3/\text{t}$. The gas content in the central F_2 mining area is the lowest due to local faults.

2.2. Profile of the Working Face. The $F_{15-17-11111}$ working face of Pingdingshan No. 13 Mine is located in the sixth section of the east flank of the F_1 mining area. It extends to the Goulifeng normal fault in the east, the boundary of the security pillar at the rise and the Dongfeng shaft in the west, the goaf of the $F_{15-17-11090}$ mining face in the north, and the boundary of the F_1 mining area in the south. The F_3 mining area is under the F_1 mining area. The schematic diagram of the $F_{15-17-11111}$ working face is shown in Figure 1. The ground elevation of the working face is $+84.1$ m, and the elevation of it ranges from -465 m to -620 m. The mining coal seam in this working face is the F_{15-17} seam whose thickness and dip angle lie in the range of $3.8\text{--}6.5$ m and $8^\circ\text{--}16^\circ$, respectively, according to the coal exploration data. In addition, the seam has a simple and stable structure.

The F_1 mining area where the $F_{15-17-11111}$ working face is located and the adjacent F_3 mining area both experienced the compound dynamic disasters of rock burst and gas outburst. The $F_{15-17-11111}$ working face, located at the boundary of the F_1 mining area and near the F_3 mining area, belongs to an outburst coal seam. It is also prone to the compound dynamic disasters.

2.3. Overview of Rock Burst Accidents in the Mine. On March 12, 2002, the first compound dynamic disaster occurred at 12 m (i.e., at the open-off cut) of the $F_{15-17-11091}$ machine lane. Rock burst occurred first, resulting in local destruction of the roadway and bursting 196 t of coal. Then, the gas concentration surged sharply, and the volume of gas emission was $3,840 \text{ m}^3$. On January 20, 2008, 594 t of coal

was burst and $32,927 \text{ m}^3$ of gas was emitted at 830 m of the $F_{15-17-13031}$ machine lane. On June 13, 2010, 1,133 t of coal was burst and $308,557 \text{ m}^3$ of gas was emitted at 272 m of the $F_{15-17-13031}$ low-level gas drainage roadway. Based on on-site cases of Pingdingshan No. 13 Mine, it was found that the gas concentration dropped first before rock burst, whereas it jumped sharply after that.

3. Methodology

3.1. Coupling Structural Model of Working Face Gas Emission and Stress. Rock burst generally occurs from the coal wall side of the working face. In the limit equilibrium zone ahead of the coal wall, stress is highly concentrated due to the suspension of overlying roof. As a result, a large amount of elastic strain energy is reserved in coal. In the high gas mine, the expansion energy of adsorbed gas is also reserved in coal.

The coupling structural model of gas emission and stress during deep high gas coal seam working face mining is shown in Figure 2.

During mining, three areas, namely, Areas A, B, and C, will be formed in front of the working face with the rupture of coal (Figure 2). Under high stress, the yield failure of coal in Area A leads to the loss of its bearing capacity, forming a pressure relief zone where the residual strength provides radial load for the internal coal. Under the support of the radial support force provided by the coal in Area A, the coal in Area B boasts enhanced strength, a great bearing capacity, and the highest stress, thus forming a stress concentration area. Stress in Area C gradually decreases to the initial rock stress, and this area is called the initial stress area.

When the working face experiences weighting, the hard roof is suspended above the coal wall, resulting in a certain range of "stress wall" in front of the coal wall. The "stress wall" gradually gets compacted, during which the gas emission is gradually reduced. Hence, a large amount of gas is accumulated inside the "stress wall." When the roof ruptures suddenly, the stress transfers to the deep area, which is equivalent to a sudden opening of the "stress wall." Accordingly, the gas emission increases sharply. Therefore, affected by mining stress, coal porosity and gas pressure will change dynamically. Xie et al. [27] held that the coal seam mining stress σ is a function where the gas pressure P and the porosity λ are variables (other parameters are constants for specific coal):

$$\sigma = \frac{(1 - \lambda_0)E}{(1 - \lambda)(1 - 2\mu)} \left[\frac{aK_0RT}{N_m S} \ln \frac{(1 + bP)}{(1 + bP_0)} - K_y (P - P_0) + 1 \right] - \frac{E}{(1 - 2\mu)}, \quad (1)$$

where λ_0 is the initial porosity of coal; P_0 is the initial gas pressure of coal seam, MPa; E is the elastic modulus of coal, GPa; μ is Poisson's ratio of coal; R is a universal gas constant, $\text{J}/(\text{mol}\cdot\text{K})$; T is the absolute temperature, K; N_m is the molar volume of gas, which equals 22.4 L/mol in the standard state; S is the specific surface area, m^2/g ; a is the adsorption

constant, m^3/t ; b is the adsorption constant, MPa^{-1} ; K_y is the compressibility coefficient of coal, MPa^{-1} .

Therefore, the stress has a significant influence on the distribution and extension of cracks in the coal. Cracks in the coal in Area A are interconnected, causing an increase in the porosity and a high permeability of the coal seam. In this case,

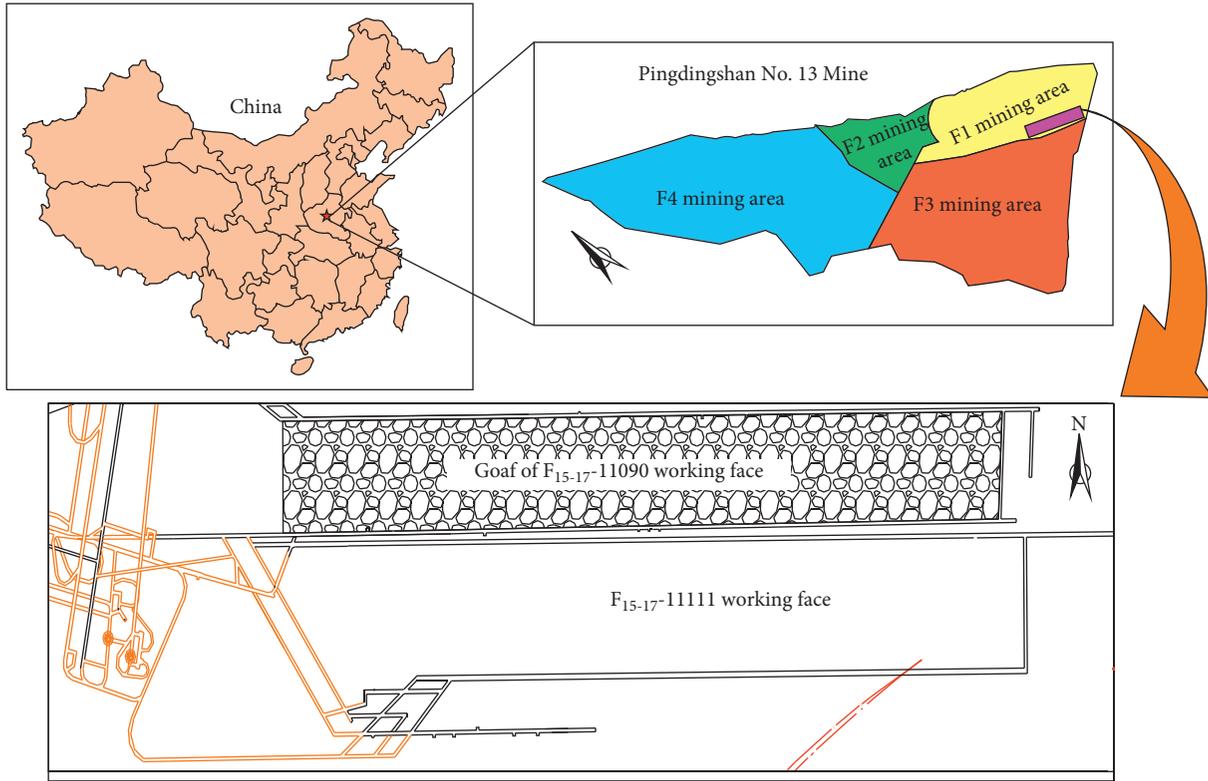


FIGURE 1: Schematic diagram of the location of the F₁₅₋₁₇₋₁₁₁₁₁ working face.

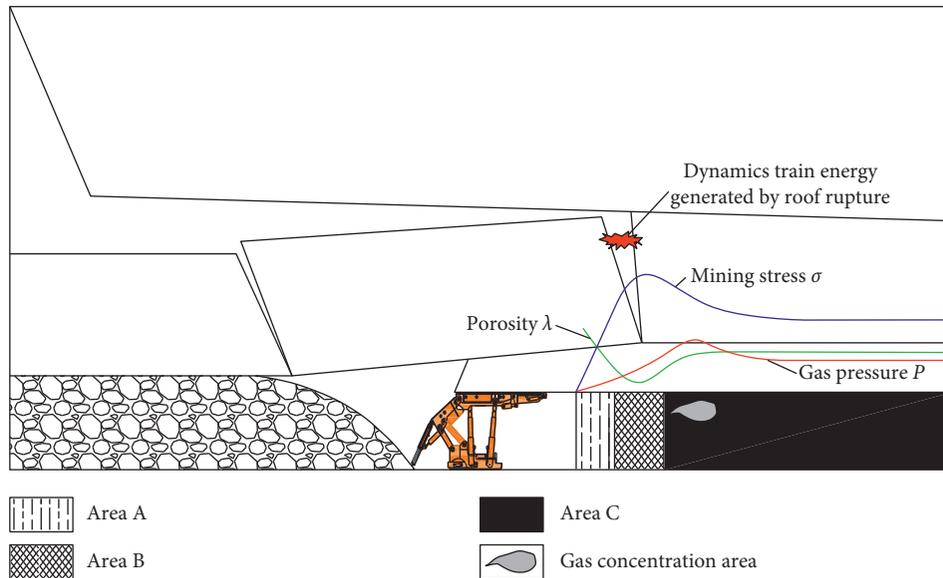


FIGURE 2: Coupling structural model of gas emission and stress in the working face.

gas can be fully emitted, so the gas content and gas pressure are relatively low. The coal in Area B is relatively integrated. Under the action of high stress, pores and cracks in the coal are compacted, bringing about a decrease in the porosity and a poor permeability. In this case, gas is accumulated, so the gas content and gas pressure are both high. Since Area B is close to the pressure relief area where the coal is ruptured seriously, a

high gas pressure gradient and a high gas content gradient tend to be formed. While the gas in Area A is emitted, the gas in Area B remains accumulated and rarely gets emitted because of the low porosity induced by stress concentration in the deep coal. The above phenomenon reflects the negative correlation between coal seam gas emission and mining stress in coal seam. Mechanically, their correlation satisfies the typical coupling.

3.2. Evolution Law of Stress and Gas in the Working Face during Mining. Since the working face is continuously advancing in the production process, the stress and gas states in the coal seam are changing cyclically and constantly. The following discussion is about the change of stress and gas states in the coal seam after the mining footage of the working face.

After the working face advances for a distance of S , the overlying load originally acting on the coal in Area S is transferred to the coal in the front, leading to a sudden rise of the stress borne by the newly exposed coal. At the same time, the amount of released gas in the coal seam is relatively small for a short time. Resultantly, a large stress gradient and a large gas gradient are formed (Curve 1 in Figure 3). When the stress exceeds the strength limit of the coal, the coal ruptures and the stress transfers to the inner part of the coal seam. Meanwhile, the cracks become interconnected after the coal ruptures, providing a channel for the migration and release of gas. The gas in the deep area transfers towards the working face (Curve 2 in Figure 3). After several ruptures of the coal in front of the working face, the stress and gas pressure gradually stabilize (Curve 3 in Figure 3). At this time, a footage of the working face is completed.

Under normal mining conditions, stress and gas pressure in front of the working face can transfer smoothly. However, once geological structures, coal seam thickness changes, and an excessively long suspended roof exist in front of the working face, stress transfer will become abnormal. Specifically, the stress and the stress gradient surge, so that gas becomes accumulated in local areas. Assuming there is an abnormal area (Area D, such as fault structures, coal seam thickness changes, soft layer thickness changes, and partings) in front of the working face, the stress transfer and variation law is shown in Figure 4. In this case, the stress no longer transfers forward along with working face advancement. Instead, it undergoes stress stagnation under the influence of Area D. As the pressure relief area (Area A) narrows, the stress peak becomes larger and increasingly closer to the working face. Besides, more and more gas is accumulated inside the coal, forming an increasing stress gradient and gas pressure gradient. A high gas content determines greater expansion energy of adsorbed gas. When Area A fails to provide enough radial support for the stress concentration area (Area B), the accumulated energy in Area B will be released outward suddenly, bringing about coal ruptures, rock burst dynamic disasters, and a rise of gas concentration.

3.3. An Early Warning Method of Rock Burst in the Deep Mine Working Face Based on the Law of Gas Emission. By analyzing stress and gas evolution in the working face during mining, it is concluded that abnormal mining conditions of the working face are likely to cause rock burst disasters. The gas concentration decreases first before the occurrence of rock burst, while it soars sharply after the occurrence. In areas where rock burst occurs, the stress increases gradually before the occurrence of rock burst, and rock burst occurs when the stress reaches the coal failure limit. Stress monitoring in

working face belongs to point monitoring which is discontinuous. When the stress reaches its maximum, the disaster is about to occur. Therefore, stress monitoring cannot support early warning. In contrast, the monitoring and control of gas concentration in the working face are continuous. As a result, based on the relationship between gas emission and stress in the working face, changes in the stress can be indirectly obtained by monitoring the gas concentration variation. In other words, rock burst can be monitored with the aid of gas concentration monitoring.

As revealed by the above analysis, the early warning of rock burst can be realized through a combination of rock burst monitoring and gas emission monitoring. In this study, by taking geological and mining conditions of the mine into account, based on the rational utilization of the existing monitoring facilities in the mine, a comprehensive monitoring scheme which can be used to monitor the gas concentration and the stress in the working face is designed, and an early warning method of rock burst in the deep mine working face based on the law of gas emission is proposed.

The flowchart of the proposed early warning method is shown in Figure 5. First of all, the monitoring points of gas concentration and stress in the working face are designed and arranged. Then, the monitoring data of gas concentration and stress are collected. Moreover, by analyzing the monitoring data, the law of gas emission and stress distribution is concluded, and the correlation between the gas concentration values and the data from the stress monitoring points is analyzed. Finally, the value of the gas concentration early warning indicator for early warning is determined, according to the data from the stress monitoring points at the moment when the dynamic changes of gas concentration are observed.

3.4. Design of Gas and Stress Monitoring in the Working Face. According to the above introduction to the proposed early warning method, a field test was carried out with the F₁₅₋₁₇-11111 working face of Pingdingshan No. 13 Mine taken as the engineering geological background. The support pressure, which could reflect the stress change in the working face, was used for predicting the weighting time and weighting step distance. In accordance with the weighting condition, the rock burst and outburst hazards could be predicted. In this study, stress monitoring in the working face was realized online through the supports. A total of nine KJ21 support pressure online recorders were installed on the supports 18#, 27#, 31#, 36#, 45#, 50#, 72#, 81#, and 90# in the F₁₅₋₁₇-11111 working face, respectively. The roof periodic weighting step distance and pressure distribution were analyzed according to the monitored data. The gas concentration monitoring was realized through the KJ-2000N safety monitoring system. The system included an MGTSV monitoring cable and two GJC40 (A) gas sensors. Of the two gas sensors, the internal gas sensor was installed in the return airway, being no more than 10 m away from the mining face. The layout of gas and stress monitoring points in working face is shown in Figure 6.

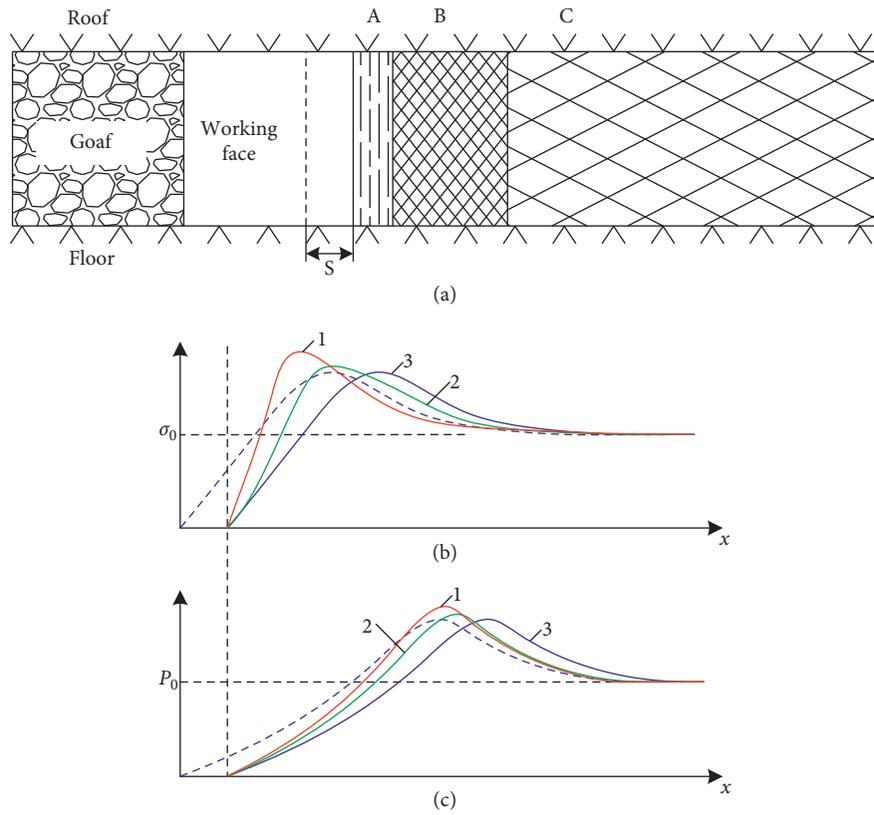


FIGURE 3: Diagram of stress and gas pressure changes.

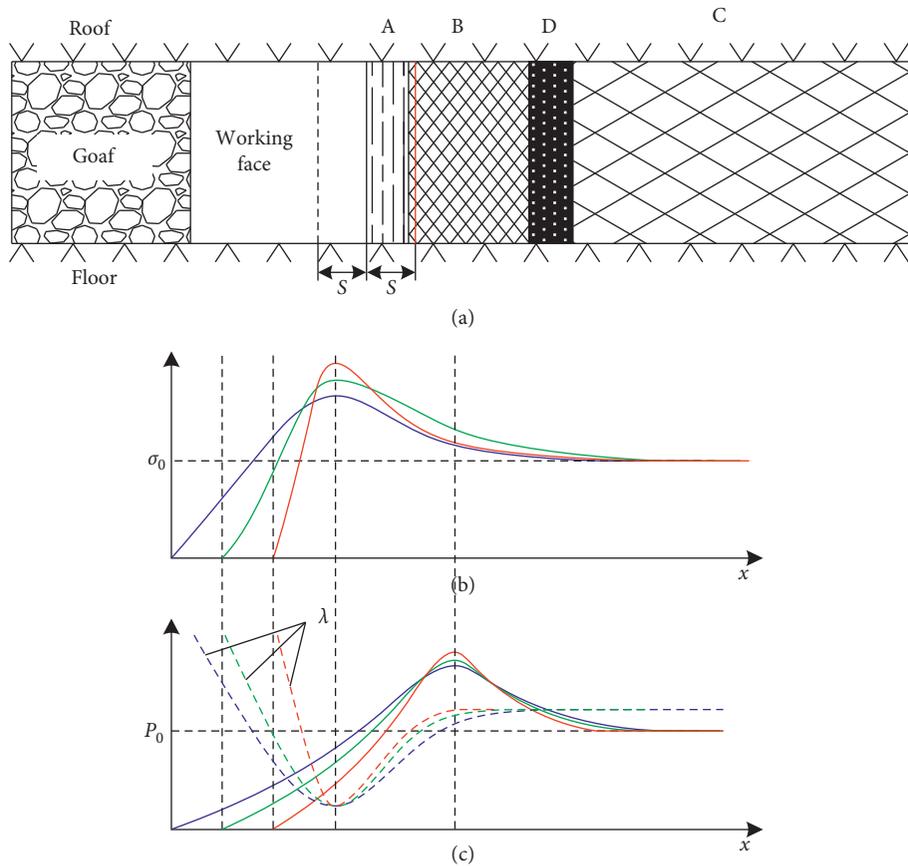


FIGURE 4: Influence of abnormal mining conditions on stress and gas pressure.

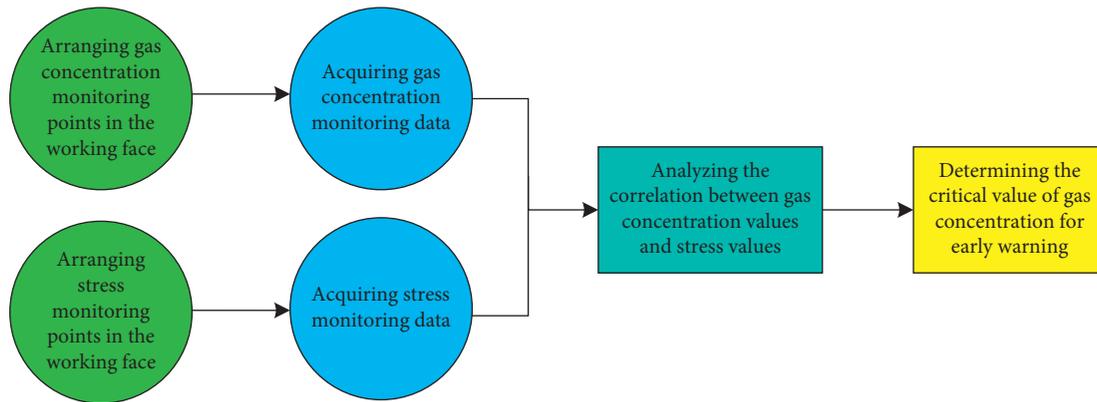


FIGURE 5: Flowchart of early warning method of rock burst in the deep mine working face based on the law of gas emission.

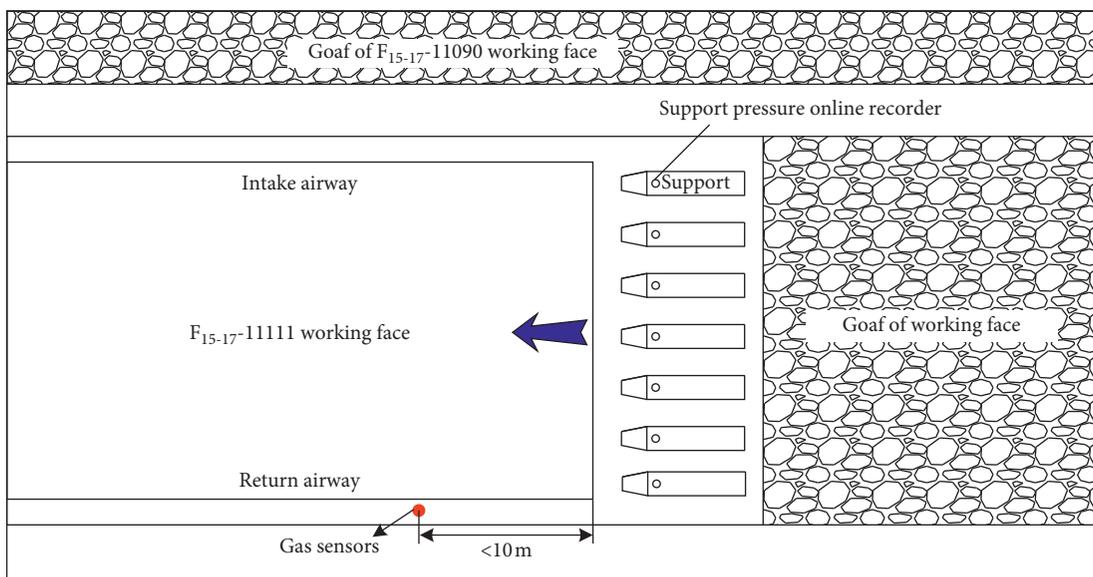


FIGURE 6: Schematic diagram of gas and stress monitoring design in the working face.

4. Results and Discussion

4.1. Law of Gas Emission and Stress Distribution in the F₁₅₋₁₇-11111 Working Face. In order to investigate the relationship between gas emission and stress distribution, the support pressure data in the working face and the gas concentration real-time data in the return airway were collected and statistically analyzed. On the basis of the analysis, the variation curves of support pressure and average gas concentration with the advancement distance of the working face are obtained (Figure 7).

According to the field data of Pingdingshan No. 13 Mine, the weighted average of support pressures in the F₁₅₋₁₇ coal seam is 25 MPa. If the support pressure exceeds the weighted average, it can be determined that periodic pressure is occurring in this area where the coal is under highly concentrated stress and possesses the risk of rock burst. Figure 7 shows that since the start of monitoring, as the advancement distance of the F₁₅₋₁₇-11111 working face increases, the roof of the working face gradually bends and sinks, accompanied

by periodic collapses. Correspondingly, the roof pressure increases to over 25 MPa, the maximum approaching 40 MPa. During normal advancement of the working face, the support pressure maintains a low value without significant changes and rarely exceeds the weighted average. However, when the working face advances to 21.4 m, 72.8 m, 108.5 m, and 140.1 m, the gas concentration of the working face falls notably, and meanwhile the working pressure of the support rises. As the working face continues to advance, roof collapse or rock burst occurs. Later, the support pressure drops, and the gas concentration jumps dramatically first and then falls. When the "8.16" rock burst occurs, the gas concentration reaches the minimum (0.03%) of the entire monitoring process, and the support pressure reaches the maximum (39.8 MPa). Afterwards, the gas concentration rises sharply to 38.65%.

4.2. Determination of the Critical Value of the Early Warning Indicator. As disclosed by the law of gas emission and stress

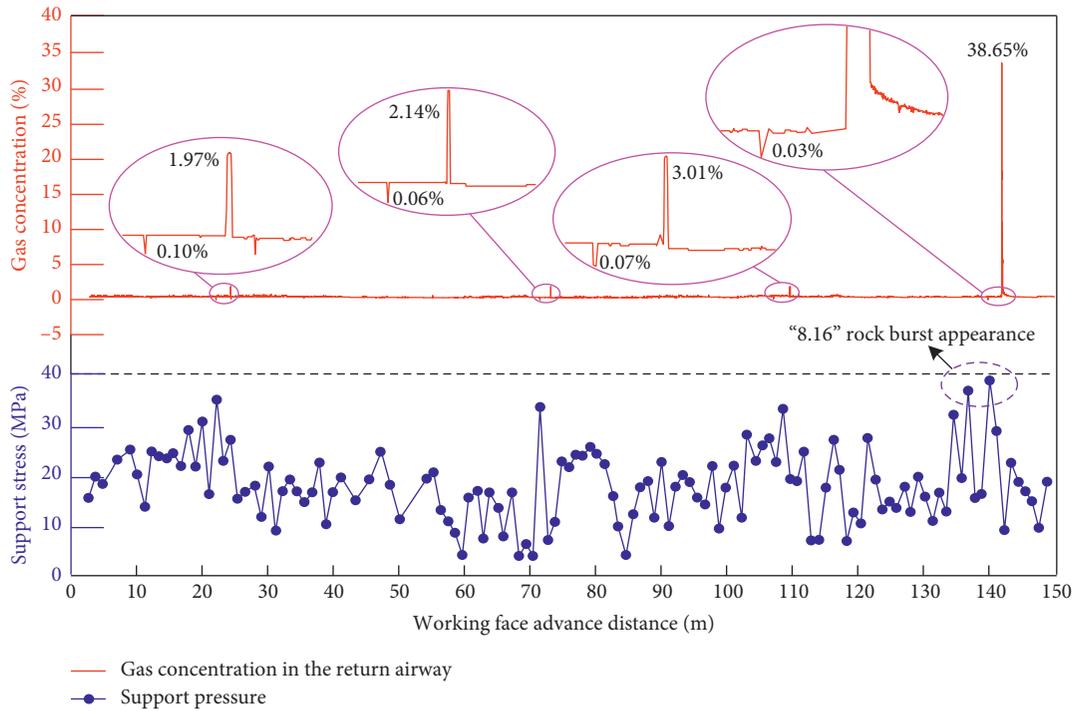


FIGURE 7: Variation curves of support pressure and average gas concentration with the advancement distance of the working face.

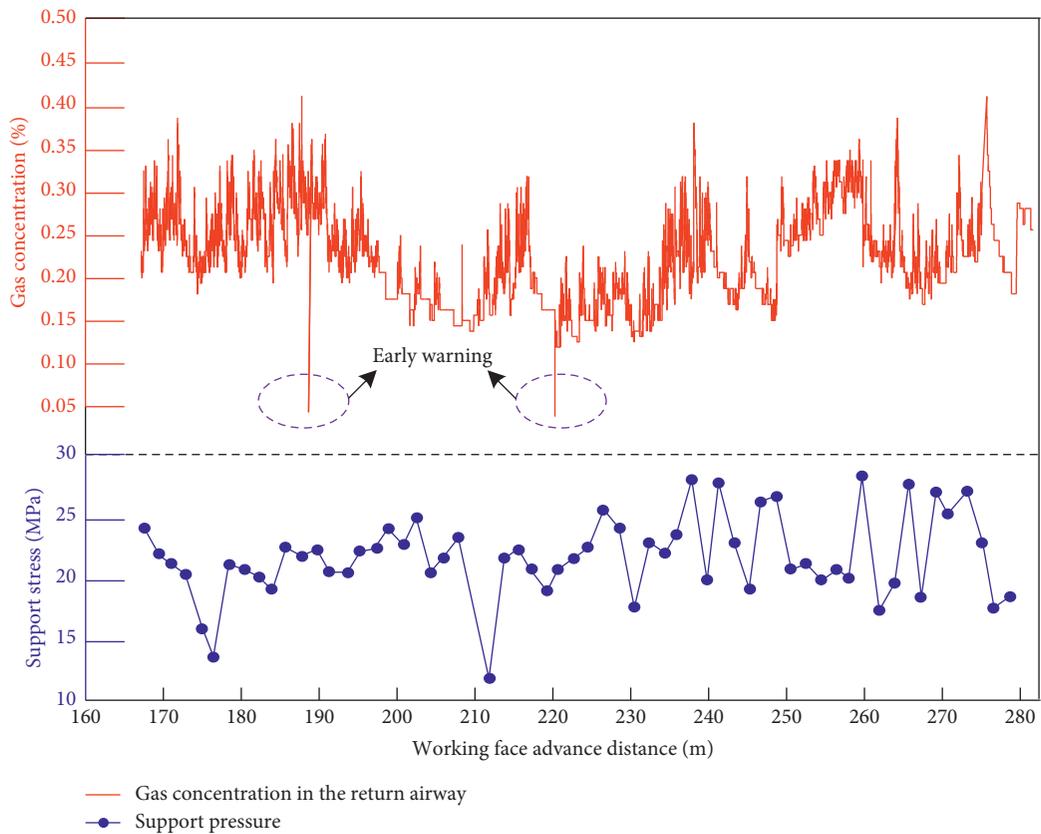


FIGURE 8: Early warning of support pressure and average gas concentration change curve after pressure relief.

distribution in the F₁₅₋₁₇₋₁₁₁₁₁ working face, during the periodic weighting, the gas emission often lags behind the periodic weighting. As the support pressure increases, the gas concentration experiences a great decrease. When it reaches the minimum, the support pressure is at its maximum. At this moment, the rock burst is the most likely to occur. By comparing the decrease in gas concentration with the usual gas concentration, the early warning of rock burst can be realized. According to the support pressure statistics during the mining of Pingdingshan No. 13 Mine, the minimum support pressure corresponding to coal and rock gas dynamic phenomena is 35 MPa, so 35 MPa is regarded as the critical value of support pressure. According to the support pressure data in the working face and the real-time gas concentration data in the return airway, during normal periodic weightings, the maximum support pressure is 34.7 MPa, and the gas concentration in the return airway ranges from 0.05% to 0.1%. When the support pressure exceeds 35 MPa, that is, when a coal and rock gas dynamic phenomenon occurs, the gas concentration is 0.03%, lower than 0.05%. Therefore, considering the correlation between the gas concentration value and the stress monitoring data, 0.05% is regarded as the critical value of gas concentration. When the gas concentration in the return airway undergoes a continuous decrease and falls to below 0.05%, rock burst warning is triggered.

4.3. Early Warning and Verification. In this study, the critical value of gas concentration for rock burst warning in the F₁₅₋₁₇₋₁₁₁₁₁ working face is determined as 0.05%. From November 2018 to January 2019, two impact hazards were predicted, with gas concentration reaching 0.042% and 0.047%, respectively, which reached the warning value, as shown in Figure 8. Therefore, when the pressure risk of impact ground pressure is detected, pressure relief measures are adopted. After pressure relief, the pressure of working face has not increased significantly, and no impact ground pressure accident occurred on the working face.

After that, the early warning results indicated rock burst risk for a total of 12 times of F₁₅₋₁₇₋₁₁₁₁₁ working face. After the pressure relief measures were adopted when the danger of rock burst was detected, the working face has been pushed forward for 400 meters, and the stopping line is safe, which has achieved significant economic, technical, and social benefits.

5. Conclusions

- (1) Through the analysis of the on-site rock burst accident of Pingdingshan No. 13 Mine, it is found that gas concentration changes regularly before and after the occurrence of rock burst. The gas concentration decreases first before the occurrence, while it jumps sharply after that.
- (2) The gas emission and the mining stress in the coal seam of the working face are negatively correlated. Mechanically, their correlation satisfies the typical coupling. In the direction of working face

advancement, the gas concentration in the working face increases as the stress decreases, and it decreases as the stress increases. In addition, the gas concentration reaches its minimum when the stress reaches its maximum.

- (3) The early warning method of rock burst in the deep mine working face based on the law of gas emission is proposed. Through field monitoring, the critical value of the gas concentration indicator for rock burst early warning in the F₁₅₋₁₇₋₁₁₁₁₁ working face is determined as 0.05%. On-site practice demonstrates that regarding the critical value as the early warning value is basically consistent with the field practical situation, and it succeeds in ensuring the safe mining of the working face.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this work.

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