Safety classification and application of coal-rock gas compound dynamic disaster in coal mine

Linchao Dai 1, 2, *
1 State Key Laboratory of the Gas Disaster Detecting, Preventing and Emergency Controlling, Chongqing, China
2 Chongqing Research Institute of China Coal Technology and Engineering Group Crop., Chongqing, China
*Corresponding author e-mail: 2012129@cqccteg.com

Abstract. Coal and gas outburst, rockburst are the most serious dynamic disaster in the coal mine production. Based on the current situation of frequent occurrence of coal and gas outbursts and rock burst disasters in deep mines, the characteristic regularity and influencing factors of coal and gas outburst and rockburst disaster are analyzed. The safety grading evaluation system of coal-rock gas compound dynamic disaster is established. And the safety grading evaluation is carried out on the impact-outburst dynamic disaster of 32 production mines. The research results show that the influencing factors of the coal and gas outburst, rockburst disaster can be divided into natural factors, technical factors and management factors. Meanwhile, the safety classification of 32 production mines coal-rock gas compound dynamic disaster are mostly II level, in line with the actual situation.

1. Introduction
In recent years, the coal mine has annually 10~25m mining speed to the depth, resulting in that the coal-rock natural occurrence conditions are more complex, and leading to China's coal mine dynamic disaster accidents remain high [1]. For example, the Pingdingshan No.12 mine 6.29 accident in 2005 and Pingdingshan No.10 mine 11.12 accident in 2007 all show the interaction characteristics of coal and gas outburst and rockburst [2-3]. At present, coal and gas outburst mine has reached nearly 1200, and rockburst mine has reached more than 170. The deep mine dynamic phenomenon is more complex, the disaster form has undergone great changes, and it can not be explained by a single theory of traditional coal and gas outburst or rockburst [4-5]. Therefore, it is necessary to unify together to carry out the coal and gas outburst and rockburst research, and it is very important to explore the reasonable dynamic safety grading evaluation system for the prevention and early warning of coal-rock gas compound dynamic disaster in the deep mining.

2. Coal and gas outburst disaster characteristic regularity and influencing factors
Coal and gas outburst is a kind of coal and gas catastrophic dynamic phenomenon which is accompanied by sound and violent energy effect in the coal mining activities. It can suddenly spray a lot of coal, gas or rock from the coal-rock body near the mining space in a very short period of time, and form a special shape of the hole in the coal-body. Since the first outburst was recorded in 1834, in view of this gas
filled coal-rock dynamic phenomenon, people began to study it and put forward a number of outburst mechanism and hypothesis. However, due to the outburst complexity and its destructive, the outburst mechanism has not yet been fundamentally resolved and has not formed the unified and complete mechanism. Currently, the mechanism has been integrated into the comprehensive hypothesis. It is concluded that the outburst is the combined effect of ground stress, gas and coal physical mechanical property. And it recognizes that the outburst itself is a mechanical process with releasing the energy, damaging the coal-body. With the coal mining to the deep, the gas and ground stress increase, the not proven geological structure, the unsuited implementation measures to the special mining geological conditions and other reasons are leading to the occurrence of coal and gas outburst.

Confined For the mine disasters, appropriate technical and management tools should be taken to give the existing prevention and suppression of natural factors, in order to eliminate or prevent coal mine accidents [6]. So the influencing factors of the coal and gas outburst can be divided into natural factors, technical factors and management factors.

(a) Natural factors. The natural influence factors are: mining depth, coal seam gas pressure, coal seam gas content, the firmness coefficient of coal, geological structure complexity, coal seam group or single seam mining, mine gas grade.

(b) Technical factors. The technical influence factors are: mine production, mining and excavation planning, outburst prevention working face quantity, ventilation mode, regional outburst prevention measure, working face average pre-drainage rate.

(c) Management factors. The management influence factors are: four in one outburst system, gas control full-time institution and personnel, gas control management system, gas control personnel training, gas control equipment with the situation, gas control equipment management calibration.

3. Rockburst disaster characteristic regularity and influencing factors

Rockburst is the dynamic phenomenon with sudden violent destruction due to the instantaneous release of the elastic deformation energy around the roadway or the rock face, often accompanied by the thrown out of coal and rock mass, loud noise and air waves. It has a very destructive, it is one of the major coal mine disaster [7]. According to the impact tendency theory, the condition for the rockburst occurrence is that the coal-body impact tendency is greater than the experimentally determined limit value. The rockburst has the characteristics: sudden, destructive complexity and so on.

(a) Natural factors. The natural influence factors are: geological structure, roof broken degree, roof, floor and coal seam impact tendency.

(b) Technical factors. The technical influence factors are: the ratio of main mining coal seam direct top thickness to mining high, mining depth, main mining seam mining high, working face support mode, driving face support mode, roof management method, first weighting interval, cycle weighting interval, mine pressure monitoring.

(c) Management factors. The management influence factors are: prevention and management institution, the number of employees trained each year.

4. The establishment of impact-outburst dynamic disaster safety grading evaluation system

At present, the deep mine dynamic phenomena (such as rockburst, coal and gas outburst) are more complex, and it is necessary to unify together to carry out the coal and gas outburst and rockburst research. Therefore, based on the analysis of the coal and gas outburst, rockburst disaster characteristics and influencing factors, the fuzzy comprehensive evaluation method is used to establish the impact-outburst dynamic disaster safety grading evaluation system according to the natural factors, technical factors, management factors, and disaster consequence severity, as shown in Figure 1.

4.1. The evaluation factors weight

The evaluation factors weight reflects the influence degree of each objective factor on the impact-outburst dynamic disaster. According to the actual characteristics of coal mine site, Delphi method combined with the expert experience is used to quantify. The specific approach is that firstly prepare a
questionnaire to score by a number of experts according to the actual situation and the importance of impact-outburst dynamic disaster on the coal mine safety production, and then calculate the average of the weight given by all experts, which is the indicator weight of the mine dynamic disaster. The weights given by the example in this paper are shown in Figure 1.

Figure 1. The impact-outburst dynamic disaster safety grading evaluation system

4.2. Fuzzy membership function construction of index
After all kinds of indexes are quantified, the fuzzy mathematics method is used to normalize. The membership function is established for each index, and the index membership degree is calculated according to the function.

The formula of target layer (Impact-outburst dynamic disaster safety index A) is:
\[ A = \sum_{i=1}^{2} A_i Q_i \]  

Where \( A_i \) is the indicator quantification score; \( Q_i \) is the indicator weight.

The formula of factor layer (Disaster indicators) is:

\[ A_i = \sum_{j=1}^{V} B_{ij} Q_{ij} \]  

Where \( B_{ij} \) is the disaster influencing factor quantification score; \( Q_{ij} \) is the disaster influencing factor weight.

\[ B_{ij} = \sum_{k=1}^{M} C_{ijk} Q_{ijk} \]  

Where \( C_{ijk} \) is the disaster influencing factor subordinate index quantification score; \( Q_{ijk} \) is the disaster influencing factor subordinate index weight.

4.3. Impact-outburst dynamic disaster safety grading standard

According to the evaluation score \( A \), a gradient of 20 is used to grade, and it is divided into five that is I~V level, as shown in Table 1.

| Security level | Security situation description       | Score       |
|----------------|-------------------------------------|-------------|
| I              | disaster risk small                 | 80≤A≤100    |
| II             | disaster risk smaller              | 60≤A<80     |
| III            | disaster risk in general           | 40≤A<60     |
| IV             | disaster risk higher               | 20≤A<40     |
| V              | disaster risk high                 | 0≤A<20      |

5. Application

5.1. Typical example

Take the Shengyuan Coal Mine in Liupanshui City, Guizhou Province as an example, the maximum mining depth of this mine is 335m, the maximum coal seam gas pressure is 1.5MPa, and the maximum coal seam gas content is 13.4m³/t. The geological conditions are complex and the coal seams are soft. It is a large coal with heavy gas hazards. Compared with the gas outburst production mine, the natural conditions are poor, and the mining replacement is tight, and there are many outburst prevention working faces. However, the mine is mining in multiple seams and adopts protective layer mining. The coal mine’s two “four in one” are sound, the gas pre-draining rate is high, and the full-time gas prevention and control institutions, personnel, systems, and equipment are complete. Therefore, despite the serious gas disaster, the gas disaster safety evaluation score is still high, 70 points. And the mine and the mining area where it is located have not experienced rock burst disasters. Although the roof of the mine is relatively broken, there are corresponding management agencies and personnel, and the safety evaluation score is 79 points.

According to the established evaluation system, the safety value of the shock-outburst dynamic disaster of Shengyuan Coal Mine in Liupanshui City, Guizhou Province is 73.42, the safety classification is level II, and the shock-outburst dynamic disaster is less dangerous. Although the mine is threatened by gas outburst disasters, reasonable technical and management measures have been adopted, so the safety evaluation score is still high, consistent with the actual disasters of the mine, and the evaluation results are reliable.
5.2. National coal mine evaluation and application
The 32 production mines impact-outburst dynamic disasters in 16 provinces are evaluated and classified by using the impact-outburst dynamic disaster safety grading evaluation system, as shown in Table 2.

### Table 2. Coal mine impact-outburst dynamic disaster safety grading evaluation

| Province | No. | Coal mine | Outburst disaster | Rockburst disaster | Total score | Level |
|----------|-----|-----------|-------------------|--------------------|-------------|-------|
|          |     |           | Score             | Weight             |             |       |
| Guizhou  | 1   | Shengyuan | 70                | 0.62               | 79          | 0.38  | 73.42 | II    |
|          | 2   | Majiata   | 84                | 0.62               | 79          | 0.38  | 82.1  | I     |
|          | 3   | Lvshuidong| 71                | 0.62               | 74          | 0.38  | 72.14 | II    |
| Sichuan  | 4   | Huashan   | 67                | 0.62               | 63          | 0.38  | 65.48 | II    |
|          | 5   | Wuhushan  | 79                | 0.62               | 66          | 0.38  | 74.06 | II    |
|          | 6   | Wulan     | 76                | 0.62               | 66          | 0.38  | 72.2  | II    |
| Neimenggu| 7   | Dingji    | 80                | 0.62               | 60          | 0.38  | 72.4  | II    |
|          | 8   | Xiaji     | 84                | 0.62               | 65          | 0.38  | 76.78 | II    |
|          | 9   | Xiaoan    | 86                | 0.62               | 66          | 0.38  | 78.4  | II    |
| Liaoning | 10  | Daxing    | 79                | 0.62               | 63          | 0.38  | 72.92 | II    |
|          | 11  | Qujiang   | 54                | 0.62               | 65          | 0.38  | 58.18 | III   |
|          | 12  | Jianxin   | 58                | 0.62               | 66          | 0.38  | 61.04 | II    |
|          | 13  | Xiayakou  | 64                | 0.62               | 65          | 0.38  | 64.38 | II    |
|          | 14  | Chenjushan| 67                | 0.62               | 65          | 0.38  | 66.24 | II    |
| Gansu    | 15  | Jinhe     | 79                | 0.62               | 65          | 0.38  | 73.68 | II    |
|          | 16  | Tianzhu   | 86                | 0.62               | 66          | 0.38  | 78.4  | II    |
|          | 17  | Baijigou  | 76                | 0.62               | 65          | 0.38  | 71.82 | II    |
|          | 18  | Jinneng   | 70                | 0.62               | 65          | 0.38  | 68.1  | II    |
|          | 19  | Duerring  | 67                | 0.62               | 44          | 0.38  | 58.26 | III   |
|          | 20  | Liyazhuang| 85                | 0.62               | 79          | 0.38  | 82.72 | I     |
|          | 21  | Shihe     | 67                | 0.62               | 67          | 0.38  | 67    | II    |
|          | 22  | Junde     | 59                | 0.62               | 59          | 0.38  | 59    | III   |
| Heilongjiang| 23 | Xingshan  | 58                | 0.62               | 59          | 0.38  | 58.38 | III   |
|          | 24  | Zhaoguan  | 89                | 0.62               | 71          | 0.38  | 82.16 | I     |
| Shandong | 25  | Songzao   | 72                | 0.62               | 67          | 0.38  | 70.1  | II    |
|          | 26  | Datong    | 69                | 0.62               | 63          | 0.38  | 66.72 | II    |
|          | 27  | Shunhe    | 77                | 0.62               | 77          | 0.38  | 77    | II    |
| Yunnan   | 28  | Gala      | 68                | 0.62               | 62          | 0.38  | 65.72 | II    |
|          | 29  | Tuzhu     | 59                | 0.62               | 61          | 0.38  | 59.76 | III   |
| Hunan    | 30  | Yipingdong| 60                | 0.62               | 61          | 0.38  | 60.38 | II    |
| Xinjiang | 31  | 1890      | 80                | 0.62               | 66          | 0.38  | 74.68 | II    |
|          | 32  | 2130      | 55                | 0.62               | 66          | 0.38  | 59.18 | III   |

From the Table 2, for the impact-outburst dynamic disasters of 32 mines in China, there are three grade I (accounting for 9.38%), 23 grade II (accounting for 71.87%), and 6 grade III (accounting for 18.75%). The results show that the situation of the impact-outburst dynamic disaster for 32 mines is better consistent with the actual coal mine disasters, and the evaluation results are reliable.

6. Conclusion
(1) The characteristic regularity and influencing factors of coal and gas outburst, rockburst disaster are analyzed. And the disaster influencing factors can be divided into natural factors, technical factors and management factors.

(2) The fuzzy comprehensive evaluation method is used to establish the impact-outburst dynamic disaster safety grading evaluation system, and it effectively achieves the comprehensive grading evaluation of rockburst disaster and coal and gas outburst disaster.
(3) Through the case verification, the safety classification for 32 mine production are mostly grade II, in line with the actual situation. And the results show that the model is reliable and can be used as a reference for the safety evaluation of gas filled coal-rock dynamic disasters in deep mine.

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