PAPER • OPEN ACCESS

In Deep Mining Working Face Rock Burst Evaluation by Multifactor Coupling Method

To cite this article: Xuanye Qin et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 242 032047

View the article online for updates and enhancements.
In Deep Mining Working Face Rock Burst Evaluation by Multifactor Coupling Method

Xuanye Qin1*, Yinghua Zhang1, Cholnam Kim1,2

1Key Laboratory of High-Efficient Mining and Safety of Metal Mines(University of Science and Technology Beijing), Ministry of Education, Beijing 100083, China
2Telecommunication Research Center, Kim Il Sung University, Pyongyang 999093, Korea (Democratic People’s Republic of)

*Corresponding author’s e-mail: qinxuanye1234@163.com

Abstract. The impact of the rock burst to the deep mining working face has been a serious problem for a long time. According to the geological structure and actual production situation in 3201 working face, this paper used the method of multifactor coupling to divide the latent dangerous area and the dangerous level affected by mining and determine the level of rock burst danger. The results of the study show that the red beds will be disturbed during the process of mining, and the red beds may be fractured in the overlying strata of the coal seam, which may lead to the rock burst. The 3201 working faces were affected by the fault FX2, fault F2-2 and the main roof which was fractured, and the 3201 working faces were evaluated by the method of multifactor coupling. The conclusion that comes to is the dangerous area at the distance 180 - 250 m to the open-off cut at the process of mining. Through the practice in 3201 working faces, this paper used the technology of micro-seismic monitoring to verify the scientific and practical of the division of the dangerous area and the dangerous level. The study is helpful to the improvement of the accuracy of the forecasting to the rock burst, and finally to realize the safe mining in 3201 working face.

1. Introduction

With the increase of the mining depth and intensity, the rock burst has been occurred in the coal seam with various types. Whether the geological structure is simple or complex, whether the coal seam is thin or thick, and whether the angle is horizontal or steep, the rock burst has been occurred. The depth of Wudong mine in Xinjiang is only 157 m, and the accident of the rock burst led to one people dead and two people injured[1]. There are many reasons for the occurrence of rock burst. And in general it can be divided into three categories, the natural geological factors, the mining technical conditions and the measures of organization and management[2]. But if the researcher needs to consider the probability of occurrence in concrete area in some certain working faces, and the factors which need to consider are more refine. Feng made the evaluation of the rock burst combined with the geological structure, the rule of the key strata movement and the strata space[3]. Xu made a division of the dangerous area combined with the geological structure, and the strata spatial structure[4]. But nowadays on the basis of various factors, there is rare research to verify the dangerous area with the technology of micro-seismic monitoring after the division of the dangerous area and the dangerous level.
2. The background of the engineering
The 3201 working face is the first working face in the 32 mining area, the thickness of the coal seam is 6.95 m, and the layout of the roadway is along the floor. The eastern of the working face is transportation roadway and the western is the ventilation roadway. The length of the working face is 135.29 m, the depth is 901 - 973 m and the mining distance is 372 m. The design of the roadway is shown in Fig 1. The geological situation of the windward shaft has three conditions. The first is it located in the area near the fault FX2. The second is located in the wing of the syncline. And the third is the side of the goaf of the mine.

![Fig 1. The diagrammatic cross-section of the rock stress superposition around the excavation working face.](image)

3. The evaluation by multifactor coupling method and the division of the dangerous area

3.1. The analysis and research of the tendency of the coal or rock burst
The situation of the roof is the immediate roof of the 3 down coal contents high level of the sand which has been phase change to the sandy mudstone. The thickness of the immediate roof is about 43 m. Due to the roof is the hard thick sandstone which is easy to form the overhangs and accumulate a large amount of elastic energy, increase the risk of the rock burst.

The main roof of the coal seam has the amaranth conglomerate which is located in above the floor about 45 m, and the thickness of the conglomerate is 7.5 - 21 m which at an average of 13.45 m. There is wave bedding which can constant aggravation the stress concentration near the working face, crossheading and the coal pillar. And the wave bedding is cross in the main roof that is the key stratum may lead to the rock burst.

In addition, there is siltstone with 299.2 m of thickness which position is 280 m to the 3 down coal seam roof. And this structure is also the key stratum that may lead to the rock burst[5].

According to the geological conditions and the mining conditions of the 3201 working face and the analysis of the surrounding rock movement, the author uses the Comprehensive Index Method to evaluate the index of the dangerous of the rock burst. The rock burst risk index under the influence of geological factors in working face is \( W_{t1} = 0.84 \), and this shows that the coal seam has a strong risk to the rock burst. The main influencing factors to the rock burst are the depth of mining, the rock burst tendency of coal seam, the hard roof rock stratum, the stress concentration and so on. The rock burst risk index under the influence of mining conditions in working face is \( W_{t2} = 0.75 \), and this shows that the coal seam has a medium risk to the rock burst (at the strong side). The main influencing factors to the rock burst are goaf, coal pillar and fault around the mining area.

Through the comprehensive comparison analysis, the risk level of the rock burst in 3201 working face is evaluated as the strong impact risk, and the index of the impact dangerous is \( W_t = \max\{W_{t1}, W_{t2}\} = 0.84 \). And the main factor which can influence the rock burst is the geological factors, and the mining depth of working face, surrounding goaf and pillar, hard roof rock and distance
from coal seam also have certain influence.

3.2. The engineering analogy evaluation between the geological structure and the rock burst
The geological structure of the working face is one of the main factors to induce the rock burst. In the vicinity of the fold axis and fault will cause the local stress concentration of coal rock, then the rock burst may occur.

The 63\textsubscript{down}03 and 63\textsubscript{down}04 working face in No.3 Jining Coal Mine had been occurred the rock burst which was caused by geological structure. This paper compared the Jining Coal Mine with the 3201 working face in geological structure to make an engineering analogy, and then made a division of the dangerous area of rock burst.

As shown in the Fig 2, the rock burst occurred near the syncline axis of the 63\textsubscript{down}03 working face. When the working face advanced to the axis of the syncline and took into account the effect of the 2 faults, the working face occurred the rock burst. Due to the existence of the inclined fault, when the 63\textsubscript{down}04 working face advanced to the place which distance to the fault is 55 m can lead to the local stress concentration, and then occurred the strong dynamic pressure. The reason above the paragraph induced the rock burst.

![Fig 2. The 63\textsubscript{down}03 working face.](image)

The general trend of coal seam of the 3201 working face is the syncline structure that is high height in the north and south coal seam and the middle low. The coal seam has a large tectonic stress near the axis. According to the actual situation of the revealing fault of the working face, the most of the faults which main trend was SE developed in the north wing of the syncline. It is expected to reveal about 19 normal faults with a fall from 0.4 - 60 m. The possibility of concealed other minor faults is not excluded in the working face. The fault just exists near the axis of syncline and the tectonic stress is strong. And it’s very likely to induce the rock burst.

Table 1. The engineering analogy table of the geological structure of 3201 working face.

| Working face | Syncline | Axial fault | Inclined fault and goaf | Impact situation |
|--------------|----------|-------------|------------------------|------------------|
| 63\textsubscript{down}03 | Yes | Yes | No | Occurred |
| 63\textsubscript{down}04 | No | No | Yes | Rock burst |
| 3201 | Yes | Yes | Yes | Possible |

According to the Table 1, it is determined that the working face which affected by the geological structure is the dangerous area of the rock burst. The influence area of the haulage roadway has a distance from 250 – 400 m to the open-off cut, and the influence area of the return airway has a distance 220 m to the rock roadway.

In addition, the return airway of the working face is adjacent to the fault FX2. Although the coal pillar is retained in the middle, the width of the protective coal pillar of the 28 m thick will gradually decrease with the advance of the working face and the stress near the fault is concentrated. It’s dangerous to induce the rock burst. Therefore, the influence area is 40 m from the working face to the rock roadway.
3.3. The evaluation of relationship between the movement of the overlying strata spatial structure and the rock burst

It is proved that the location of rock burst in longwall working face can be predicted by using the spatial structure of overlying strata. The emphasis is on the special stage, such as the first weighting of the main roof, the single working face of the advanced distance that equals to one longwall working face length, the double working faces of the advanced distance that equals to two longwall working face lengths, the triple working faces of the advanced distance that equals to three longwall working face lengths and the two caving working faces of the advanced distance that equals to one longwall working face length of the second times. Therefore, according to the different stages of the working face that the coal mine can make sure the risk of the rock burst[6].

(1) The first fracture of the main roof

With the advance of the working face, according to the experience of other working faces in this mine, the first weighting of the main roof will occur in the working face which has been pushed 50 – 60 m. This stage delimited the dangerous area that the distance to the working face is 50 – 120 m.

(2) The formation stage of the “S” type overlying strata spatial structure

When the first fracture of the main roof of the 3201 working face is completed, the upper strata will move together with the same strata in the upper section. That is the upper strata of the main roof will move together, and the overlying strata spatial gradually transforms from the "O" type structure to the "S" type structure, as shown in the Fig 3.

Fig 3. The "S" type overlying strata and the high stress field.

Close to the side of the goaf side entry is the main distribution area of the "S" type overlying strata. The supporting points of each rock beam of "S" type overlying strata spatial structure are on the side...
of the goaf side, while the fracture line of the rock beam is on the side of the solid coal. Therefore, the dangerous area of this stage is the whole haulage roadway [7].

(3) The stage of the periodic weighting

After the first weighting of the working face, the main roof began to appear periodic and regular collapse. The risk of danger zone within the scope of 70 – 100 m in front of the working face will be enhanced before the main roof will have the periodic weighting.

(4) The stage of the 3201 working face of the advanced distance that equals to one longwall working face length

With the advance of the working face to about 135 m, the working face enters the advanced distance that equals to one longwall working face length. The influence scope is 50 – 100 m in front of the working face.

(5) The stage of the double working faces of the advanced distance that equals to two longwall working face lengths

When the working face is extracted from 115 – 180 m, the working face formed the double working faces of the advanced distance that equals to two longwall working face lengths with the adjacent 3113 working face. The influence of mining on the upper red bed (purplish red conglomerate) is evaluated by numerical simulation along the sloping and trending direction.

The experiment is simulated by the FLAC3D and the size of the model is 390×500×500 m. The key parts of the model are encrypted and the grid density is 3×4×4 m. The Fig 4 is the stress state of the red bed before mining. The value of the stress cloud map of the red bed above the stope is -3.50E1-3.00E1. The Fig 5 and the Fig 6 are the stress state of the red bed during the mining process. The value of the stress cloud map of the red bed above the stope is -2.50E1-1.0E1. The value of stress decreases by nearly half, with the possibility of instability.

Fig 4. The vertical stress cloud chart of red bed above coal seam before mining.
Fig 5. The vertical stress cloud chart above coal seam during the mining process.

From Fig 5 and Fig 6, it is shown that the red bed may be disturbed during the mining process of the 3201 working face, the red bed in the overlying strata of the coal seam may break, and this disturbance to the red bed may induce the rock burst. Because it is far away from the ground, it will not affect the ground, but there is a possibility of rock burst induced by mine earthquake in the 3201 working face. Moreover, the working face is affected by fault FX2, fault F2-2 and main roof fracture. The dangerous area delineated at this stage is 180 – 250 m away from open-off cut.

3.4 The evaluation of rock burst induced by coal pillar
The 3113 working face which is adjacent to the east side of the 3201 working face is a goaf. There is no coal pillar in the 3201 working face, and the west is the unexploited area. Therefore, there is no influence on the ground pressure caused by the coal pillar in the 3201 working face.
3.5 The evaluation of multi-factor coupling and the division of the dangerous area

According to the evaluation of multi-factor of the risk of rock burst and the degree of the factors that induce the impact of rock burst, the position and risk of the dangerous areas are superimposed, and these dangerous areas are divided into three categories, as shown in the Table 2 and the Fig 7.

Table 2. The division of the dangerous area of the rock burst of the 3201 working face.

| Serial number | Distance to open-off cut/m | Main cause | The degree of dangerous |
|---------------|---------------------------|------------|------------------------|
| 1             | 40-Entry to the rock drift.| Adjacent the 3011 goaf and the No.9 fault. | Commonly               |
| 2             | 50-120                    | The first pressure of the main roof | Moderately             |
| 3             | 120-250                   | The stage of the 3201 working face of the advanced distance that equals to one longwall working face length | Highly                 |
| 4             | 250-400                   | The stress concentration area of the syncline wing and axis | Moderately             |
| 5             | 50-220                    | The first pressure of the main roof and the stage of the 3201 working face of the advanced distance that equals to one longwall working face length | Moderately             |
| 6             | 220- Entry to the rock drift. | The stress concentration area of the syncline wing and axis | Commonly               |

Fig 7. The effect picture of the evaluation of multi-factor of impact dangerous area superposition.

4. The application of the technique of micro-seismic monitoring

Rock failure occurs under the action of stress. And along the rock failure, the rock burst and the sound waves will occur at the same time[8]. After the data processing, the location of the fracture can be determined and displayed in the three-dimensional space[9]. As shown in Fig 8, the principle of rock mass stress field analysis based on micro-seismic monitoring is as follows: the difference of high stress leads to rock mass fracture and produces the events of rock burst. On the contrary, it can
describe rock mass fracture field according to the distribution characteristics of the events of the rock burst, and then can analyze the distribution characteristics of rock mass stress field[10].

![Diagram](image)

**Fig 8.** The verification of MS event in dangerous rock burst zone.

**Table 3.** The contrast table of rock burst prediction and actual vibration occurrence in the 3201 working face.

| The main reason of predicting and warning | The estimated drawing pace (m) | The actual occurrence drawing pace (m) | The description of the destroy degree |
|------------------------------------------|-------------------------------|----------------------------------------|--------------------------------------|
| The first pressure                        | 52                            | 55                                     | More mild and no damage              |
| The advanced distance that equals to one longwall working face length of single working face | 130                            | 138                                    | The pressure of the return airway is more apparent |
| The structure(fault)                      | 135                            | 139                                    | The vibration energy is 2363J, and the dynamic pressure is obvious |
| The space structure of "S" type overlying strata | 122                            | 128                                    | The underground shock is obvious, and the vibration energy is 2162J |

In the mining process of the 3201 working face, there is no destructive rock burst in the field, but combined with the results of micro-seismic monitoring, it can be found that a number of large shock
9

events have occurred in the prediction and early warning area, as shown in the Table 3, and some events are strong in the underground, and the dynamic pressure is obvious. The occurrence of this situation mainly indicates that the prediction results are in good agreement with the on-site vibration occurrence.

5. Conclusion
(1) The condition of the rock burst is the result of the interaction of various factors, and the evaluation of the method of the multi-factor coupling can accurately predict the dangerous area and divide the risk degree.

(2) It is proved that the use of micro-seismic monitoring combined with the theory of multiple factors coupling can effectively predict the rock burst.

(3) Based on the relationship between the movement law of the overlying strata and the rock burst, it introduces the several stages of the strata movement in the 3201 working face and the prediction model of the micro-seismic monitoring which is based on the 3201 working face and other working faces. Finally, the normalization of prediction of the weighting of working face is realized.

References
[1] Jiang YD, Pan YS, Jiang FX. State of the art review on mechanism and prevention of coal bumps in China. Journal of China Coal Society 2014;39(2):205-213.
[2] Qian MG, Shi PW, Xu JL. Mining Pressure and Strata Control. Xuzhou: China University of Mining and Technology Press; 2010.
[3] Feng YY, Liu TC, Yin ZD. Coalface rock burst evaluation by multifactor coupling method. Safety in Coal Mines 2013;44(8):196-199.
[4] Xu CH. Multi factor coupling analysis and dangerous zone classification of risk of rock burst in working face. Energy Technology and Management 2014;39(6):82-83.
[5] Xu JL, Qian MG. Method to distinguish key strata in overburden. Journal of China University of Mining & Technology 2000;29(5):463-467.
[6] Wang CW, Jiang FX, Sun QG. The forecasting method of rock-burst and the application based on overlying multi-strata spatial structure theory. Journal of China Coal Society 2009;34(2):150-155.
[7] Jiang FX, Zhang XM, Yang SH. Discussion on overlying strata spatial structures of longwall in coal mine. Chinese Journal of Rock Mechanics and Engineering 2006;25(5):979-983.
[8] Cheng YH, Jiang FX. Study on Microseismic Monitoring and Control Technology for Rock Burst in Mines. Beijing: China Coal Industry Publishing House; 2011.
[9] Jiang FX. Application of microseismic monitoring technology of strata fracturing in underground coal mine. Chinese Journal of Geotechnical Engineering 2002;24(2):147-149.
[10] Qi QX, Li XL, Zhao SK. Theory and practices on stress control of mine pressure bumping. Coal Science and Technology 2013;41(6):1-5.