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Roadway Driving Along next Goaf in Thick Seam with High Outburst-Proneness in Deep Mine Based on Microseismic Monitoring

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Abstract. According to HuaFeng Coal Mine, it is explored that the solutions of coal pillar bearing large, leaving hard, and prone of rock burst in thick seam with high outburst-proneness in deep mine based on microseismic monitoring. Taking No.1411 face for instance, the study identified the technical proposal of vertical completed pillarless entryway driving along goaf. High roadway deformation and frequent rock burst of the mine roadway caused by the roadway driving along next goaf with a narrow coal pillar between No.1410 blew drift and No.1411 up drift were treated and controlled. The research results show that: the convergence between roof and floor was reduced by 132mm. The mine earthquake levels, released energy and frequency decreased significantly. Above M=0.9 were reduced 86%, 94% reduction in the release of energy.

Introduction

Rock burst is a more typical phenomenon of mine dynamic disaster, mainly for sudden violent release process of gathered elastic strain energy in the coal and rock mass[1-2]. Especially with the increase of coal mining depth, rock burst is more and more prominent[3-5]. Almost all countries in the world are under the threat of rock burst in different degrees, including the former Soviet Union, Poland, South Africa, Germany, the United States, Canada, India, UK, China and many other countries and regions[6-7].

There are a couple of factors contributing to rock burst, including mining depth, coal seam properties, properties and characteristics of roof and floor, geological structure, mining methods, pillar status, mining sequence, roof control method[8]. Among those factors, coal pillar stress concentration is fairly important. In DouLinming's division of rock burst, Coal pillar rock burst is due to the surrounding roadway coal pressure increased metastable to limits， and the sudden release of energy aggregation. Therefore, the stress concentration on the coal pillar not only have an influence on coal seam mining, but also form the impact conditions on the lower coal seam which can induced rock burst. Huafeng Coal Mine is kilometer-level in depth with serious rock burst disasters. March 8, 1992, the first rock bursts of Huafeng Coal Mine occurred in No.2406 (1) up drift, resulting in 15m roadway serious damage and 70% shrinkage in roadway cross section within 30m of the working face [9]. Since the first rock burst occurred, the rock burst above M=0.5 had happened more than 28,000 times, in which above M=1.0 happened more than 2900 times, above M=2.0 happened more than 10 times, and the largest magnitude richter is 2.9 in Huafeng Coal Mine. The typical rock burst accidents also have "4.27" rock burst accident occurred in No.1407 in 1996 and "3.11" rock burst accident occurred in No.3406 in 2001 in Huafeng Coal Mine[10-12]. Coal pillar rock burst had great destructive power, with the gradual extension of coal mining to the deep, coal pillar rock burst will become increasingly serious. In order to prevent the occurrence of coal pillar rock burst, improve the working environment and to increase the recovery ratio, Huafeng Coal Mine tried to study of roadway driving along next goaf, and achieved certain results in No.1411 working face.

1 Wide Range of Rock Burst Theory of “Grooming” Area Base on Concentrated Static Load

1.1 Local rock burst start-up energy conditions

Figure 1 depicts the rock burst model for fully-mechanized face like figure 1. The rock burst generally occurs in coal wall side of the roadway workface. The start of rock burst influenced by coal stress concentration and hard strata faulting above stope. The concentrated static load E_0 for limit equilibrium zone in face coal wall is get by Formula （1）.

$$E_0 = \frac{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\mu(\sigma_1\sigma_2 + \sigma_1\sigma_3 + \sigma_2\sigma_3)}{2E} \tag{1}$$

E_0 is compression elastic energy of slow accumulation for coal wall limit equilibrium zone ; E is elastic modulus; μ is poisson ratio; $\sigma_1\sigma_2 + \sigma_1\sigma_3$ are 3 principal stress in this position.

Dynamic load E_d from hard roof fracture is get by Formula（2）.

$$E_{\rm d} = E_{\rm d0} R^{-\eta} \tag{2}$$

E_d is roof break elastic energy transfer to the limit equilibrium zone in coal wall; E_d is initial energy during fracture of roof, it can be monitor by the microseismic; R is distance between roof fault location and limit equilibrium zone of coal wall, it get by microseismic location; η is energy attenuation index of elastic waves in coal rock medium.

According to the shock initiation theory of the rock burst, the energy condition of impact start in roadway coal wall side like figure is:

$$E_0 + E_{\rm d} - E_{\rm c} > 0 \tag{3}$$

$E_{\rm c} = \sigma_{\rm c}^2 / 2E$ is the minimum energy of dynamic failure of the limit equilibrium zone in coal wall, $\sigma_{\rm c}$ is uniaxial compressive strength of coal [13].

1.2 Dredge idea of regional concentrated static load

We can conclude from Formula（3）, that the energy source of rock burst is mainly divided into 2 categories: static load near field system and dynamic load from far field system. The static load of the system is mainly based on the concentrated compression Elastic energy during surrounding rock and bend elastic energy before floor (rock stratum) bending fracture, the dynamic load includes the rock burst wave from rock strata activity and extractive blasting, it mainly base on instantaneous compression Elastic energy from hard roof fracture, floor fracture, underground blasting.

In the light of the rock burst starting theory，the energy of the rock burst starting can be static load near field system and dynamic load from far field system, but fundamentally speaking, static load near field system must be reached critical condition. In other words, dynamic load from far field system is help it reached the critical condition, it is difficult to complete the impact start if static load near field system not large enough, dynamic load will be consumed when pass to the static load area[14-15].

Due to the continuously formation of working face goaf, bearing body of overlying strata changes in consequence, concentrated load of high rock stratum, eventually becomes the static load source of the rock burst in the extractive space. That is to say, working face mining is closely related to concentrated static load needed by rock burst start in local roadway. So rock burst prevention research is based on research of concentrated static load adjustment law, it also the first step to control rock burst. Focus on migration, concentration of concentrated static load, cannot through blasting destressing and blocking. Obviously, the most effective way is to optimize mining layout, dredge concentrated high stress and to avoid the formation of high stress concentration areas.

2 Roadway Layout of Gob Side Entry

Coal seam 4 is the main coal seam in Huafeng Coal Mine. The coal dip 30°~34°, the average thickness is 6m. coal seam 4 is easy to catch fire, ignition period during 3 ~ 4 months, the shortest time is 42 days. Coal seam 4 had strong bump proneness, which is the serious rock burst seam. Therefore，coal seam 4 under the threat of rock burst when it was mined.

No.1411 working face uses longwall caving mining technology, which is the main coal mining face in Huafeng Coal Mine. The first three paragraphs on the No.1411 up drift uses narrow coal pillar driving along next goaf, which stays 2~3m. No.1140 under drift drives along the seam roof, and No.1411 up drift drives along the seam floor. Roadway support use anchor with mesh. It may distinguish that the No.1411 up drift is in rock burst prone areas according to "the principle of superposition movement". In practical application, serious roadway deformation and many rock burst microseisms cause a great threat to production safety. Figure 1 shows the rock burst occurrence in No.1411 up drift.

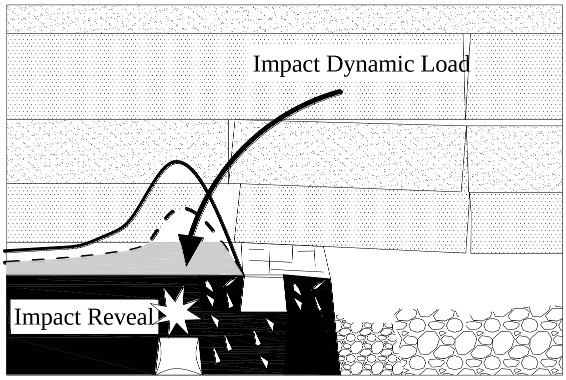


Figure 1. The rock burst occurrence in No.1411 up drift by "the principle of superposition movement".

After research, it uses vertical completed pillarless entryway driving along goaf from the fourth zone on No.1411 up drift, which is optimal force state. No.1410 under drift and No.1411 up drift are vertical relationship. No.1411 up drift driving along the floor, whose lower working slope is highly consistent with the roadway floor, so No.1411 up drift is just in pressure relief regional. No.1411 up drift uses U-shaped roof support and guniting to closed fire. Figure 2 shows the vertical completed pillarless entryway driving along goaf.

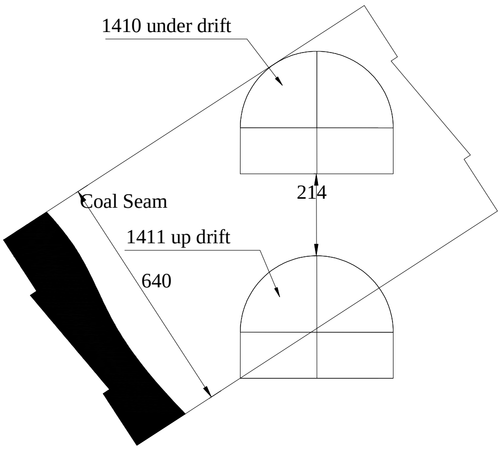
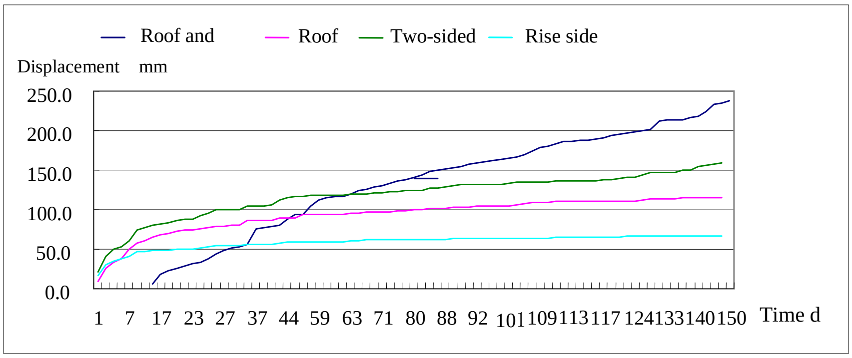


Figure 2. Roadway layout schematic.

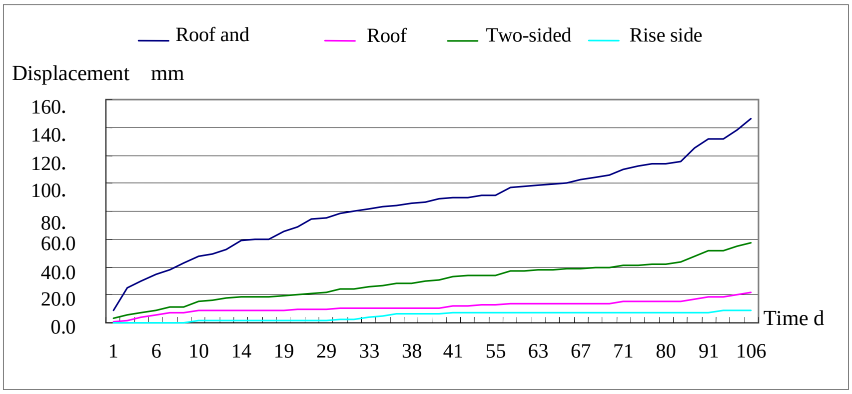
3 Comparative Analysis of Roadway Deformation Parameters on No. 1141 Up Drift

3.1 Comparative analysis of surface displacement

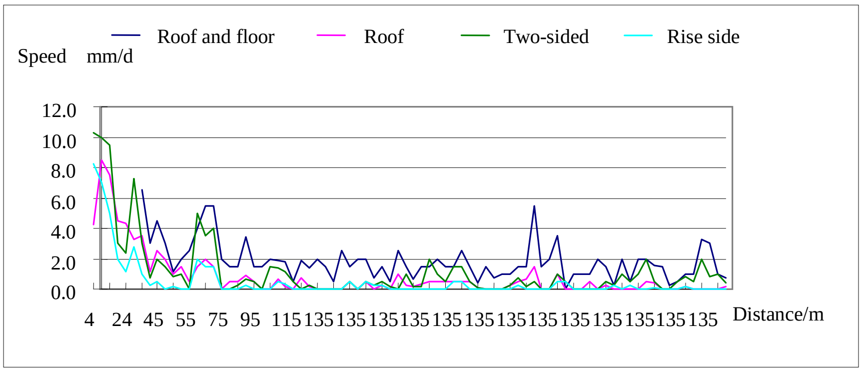
No.1411 up drift sustains high ground stress and also sustains intense abutment pressure by mining. Roadway pressure surrounding rock mining influence to bear several times, even ten times the original stress, which result large deformation and severely damaged the first three zone on No.1411 up drift. By using vertical completed pillarless entryway driving along goaf, the deformation of the fourth, fifth zone on No.1411 up drift and the No.1410 under drift has been effectively controlled. The figure 3 shows the curve of the surface displacement and speed.



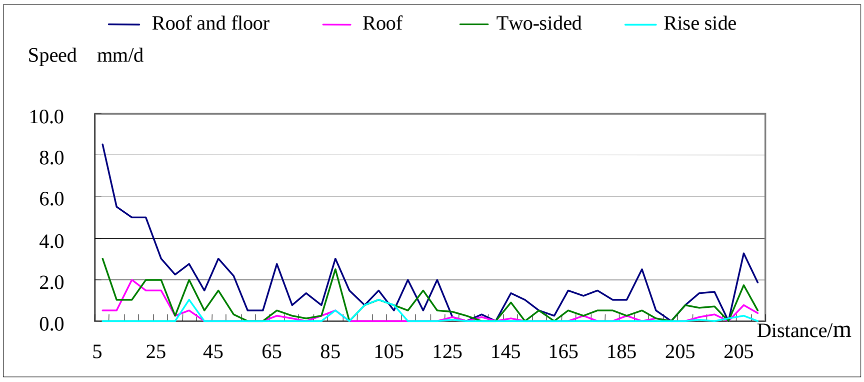
(a) Displacement curve chart of primary support zone surface for No.1411 up drift



(b) Displacement curve chart of test zone surface for No.1411 up drift



(c) Displacement velocity curve chart of primary support zone surface for No.1411 up drift



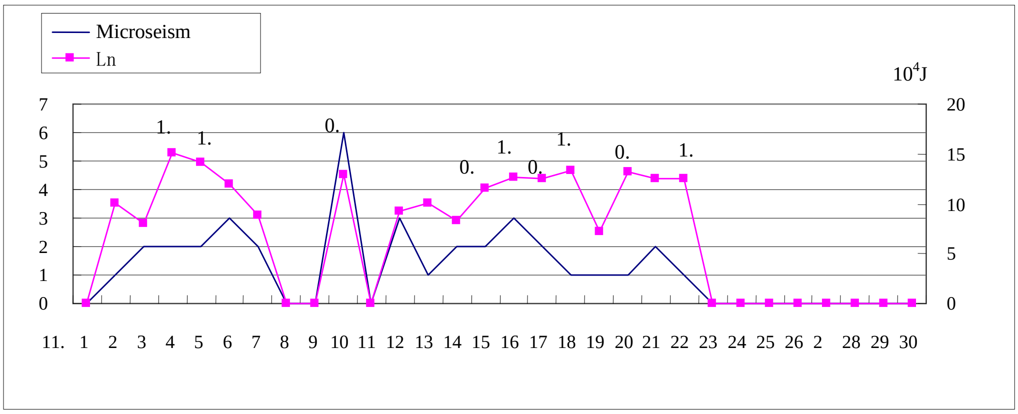
(d) Displacement velocity curve chart of test zone surface for No.1411 up drift

Figure 3. Supporting deformation contrast for original and now in 1411 up drift.

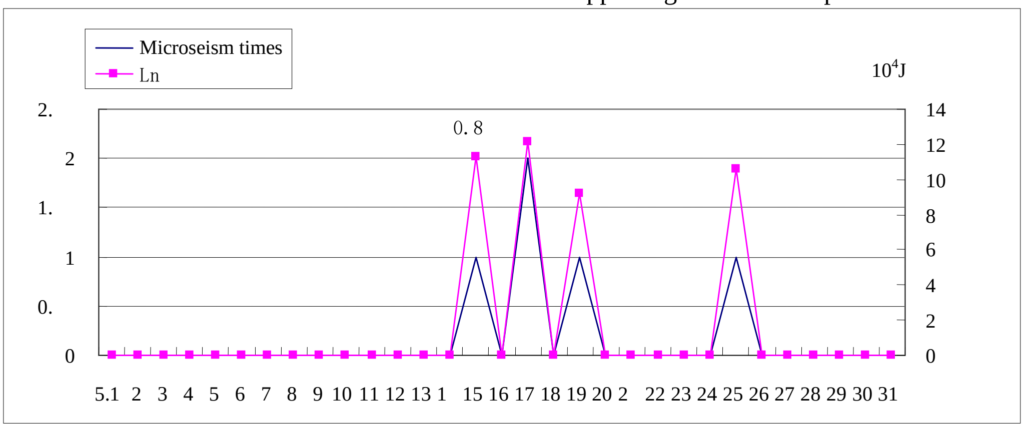
By comparing the two sets of data, the speed of convergence between roof and floor reduced from 1.86mm/d to 1.34mm/d, the speed of roof subsidence reduced from 0.77mm/d to 0.20mm/d, the speed of two-sided displacement from 1.07mm/d to 0.52mm/d. Therefore, use this plan 1411 up drift is blew 1410 under drift, displacement of the roadway surface is obviously decreased, and deformation of the roadway is obviously controlled.

3.2 Comparative analysis of micro-seismic monitoring

BMS micro-seismic monitoring system is used in No.1411 up drift in Huafeng 4 coal seam which is serious rock burst coal. Figure 4 shows that Micro-seismic monitoring results of the first three zone and the fourth, fifth zone.



（a）Trend chart of microseism before supporting in No.1411 up drift



（b）Trend chart of microseism after supported in No.1411 up drift

Figure 4. Micro-seismic monitoring results of the first three zone and the fourth, fifth zone.

By comparing the rock burst of the first three zone and the fourth, fifth zone and above M=0.5 mine earthquake, we can see that in the first three zone above M=0.5 happened 9 times and release energy for 79.8×10^5J， in which M=0.6 happened 1 time, M=0.8 happened 1 time， M=0.9 happened 2 times, M=1.1 happened 1 time， M=1.3 happened 1 time, M=1.6 happened 1 time， M=1.8 happened 2 times， in the fourth， fifth zone occurred only once M=0.8 mine earthquake in the deep surrounding rock which did not induced rock burst and release energy for 3.26×10^5J. Therefore, disposed the 1411 up drift which can be driven in geostress relief area below the No.1411 up drift goaf. According to the prediction in advance, the dynamic disasters idea of harmless tremors is under control successfully.

4 Construction Management Key Issues

(1) Roof management. The No.1411 up drift and No.1410 blew drift are overlapping layout, coal pillar only about 2m, therefore, it is extremely difficult to control the roof in construction site, so the roof management becomes the key issue. We often use of a pre anchored bolt and a collision wedge method to control the roof in the process of construction, In addition to narrow the roof control distance and control circulating footage strictly. Make a blasting method of multi drill less charge in heading face, the distance of the peripheral eye to contour with the roof condition increases appropriately, and use hand picks to fix roof after blasting.

(2) Water drainage and gas management. Exploring stockpile water in goaf during No.1411 up drift driving, strictly implement the construction mode of excavation after probing. Use the pressure relief hole of prevention rock burst, excavating 30m and driving 20m, hold 10m safe distance. And use the method of old air pressure dilution to prevention. It can drilling and blasting when the harmful gas concentration is less than 1% in repeated pressure wind heading face, carbon dioxide concentration is less than 1.5%.

(3) Prevention and control of rock burst. Roadway driving mode adopt intermittent tunneling, unloading and tunneling construction before roadway driving, pressure relief for each 20m, at least have 10m pressure relief zone in heading face. Layout of drill hole: arrange 2 floor depressurization hole in heading face, the drilling depth was 30m and 20m.

5 Conclusion

Strictly enforce the staff number restriction during driving, precisely working people on the head of tunnel no more than 9. Strictly implement against the fixed system for equipment and material. Strictly enforce the provisions when shooting, and the time of the hiding shoot is more than 30 minutes, the radius is more than 150m. Strictly implement coal monitoring and dangerous coal quantity index: the dangerous coal quantity index is 2.6Kg/m in 1411 up drift. Monitoring the coal quantity index among Heading face and under the head 10m range everyday.

By combining the best stress state of driving roadway along goaf, use the vertical layout of tunneling along goaf without coal pillar for No.1411 up drift and No.1410 under drift, make the roadway deformation, reduce the roadway maintenance costs and rock burst of the roadway, created a safe working environment. The practice presents that the vertical layout of tunneling along goaf without coal pillar is suitable for Huafeng Coal Mine.

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