Research on prevention of rock burst with relieving shot in roof

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Abstract

During hard roof rupture or slip instability with the sudden release of large amount of elastic energy, rock burst will be caused by violent shock easily. Based on the geological conditions of 6303 working face in Jisan Colliery, numerical simulation was carried out systematically of relieving shot in roof, then the reasonable parameters of relieving shot was provided. The results of danger-breaking measures of relieving shot in roof on-site shows that the danger of rock burst is reduced with fractured circle connected and values of electromagnetic emission and drillings decreased.

Keywords: hard roof; rock burst; relieving shot; danger-breaking

Nomenclature

\begin{tabular}{|l|}
\hline
$M$ & roof rock above coal wall moment \\
$L$ & roof weighting step(m) \\
$E$ & roof rock elastic modulus(Pa) \\
$J$ & roof end inertia moment(m$^4$) \\
\hline
\textbf{Greek symbols} & \\
$\varphi$ & roof rock bending subsidence angle(\degree) \\
\hline
\textbf{Subscripts} & \\
$q$ & unit length load of roof and overlying strata additional load( N/m) \\
\hline
\end{tabular}

1. Introduction

With the increase of depth and mining intensity of coalmine in China, rock burst which seriously threatens to the safety of coalmine is getting worse. Practice has shown that many rock burst accidents are usually caused by the movement of thick and hard roof strata which suddenly caves after mining\cite{1-4}. Several rock burst accidents of 6303 working face are typical of this phase in western sixth coal mining area in Jisan Colliery\cite{5-6}. The auxiliary roadway of 6303 working face has occurred more severe rock burst accidents for many times which affected the normal excavation of roadway with severe deformation and instability of roadway. The worst rock burst accident, which showed the 6303 auxiliary roadway affected up to 30 m, highlighted to 1.5–2.0 m of physical coal side, roof sank to 0.2–0.5 m and roof separated with coal seam, occurred during the coalface mined in November 2004. Accompanied by the large sound, the electrical equipment was turned within the area, after that, many small shocks and mining-induced shocks occurred. In order to ensure the safety of coalmine, many control measures were adopted, one important measure of them was relieving shot in hard roof.
2. Geological conditions of mining area and coalface

The western sixth coal mining area is located in northern areas of west of glue roadway, southern of north Auxiliary Roadway. The eastern coal seam is higher than the western coal as a whole. The distance of mining area is 1800 – 1900 m from east to west, 2200 m from north to south and the mining area is about 3.9 km². The third coal seam was first mined with the floor elevation - 600 – - 710 m, coal thickness 7.25 m, average coal thickness of 5.5 m in this mining area. The main roof of coal is sandstone, fine sandstone, siltstone and the average thickness of the hard and thick roof is 26 m.

The 6303 working face is the fourth coalface with the length 239.8m from north to south and the mining depth 600–710 m in sixth coal mining area. The coal seam is located in Shanxi Coal Group 3 with the seam thickness 6.8 m and the value of \( f \) of roof is 8–10.

3. Influence of hard roof on rock burst

Research shows that structure of roof rock, especially hard and thick sandstone roof above the coal seam, is one of main factors that lead to the occurrence of rock burst, the main reason is that hard and thick sandstone roof tends to accumulate a lot of elastic energy. During hard roof rupture or slip instability with the sudden release of large amount of elastic energy, rock burst which is divided into coal-roof type(impact pressure type) and roof type(impact type) will be caused by violent shock easily[1].

According to Абиль приложений’s view in former Soviet Union, elastic energy in coal is made up of three parts of volume changing elastic energy with \( U_v \), deformation elastic energy \( U_f \) and roof bending elastic energy \( U_w \), namely

\[
U = U_v + U_f + U_w
\]

Among them, roof bending elastic energy \( U_w \).

\[
U_w = \frac{1}{2} M \varphi
\]

where \( M \) is roof rock above coal wall moment; \( \varphi \) is roof rock bending subsidence angle.

Therefore, accordingly Obtaining bending elastic energy during roof first caving.

\[
U_w = \frac{q^2 L^5}{576 EJ}
\]

Therefore, accordingly obtaining bending elastic energy during roof periodic caving.

\[
U_w = \frac{q^2 L^5}{8EJ}
\]

where \( q \) is unit length load of roof and overlying strata additional load, N/m; \( L \) is roof weighting step, m; \( E \) is roof rock elastic modulus, Pa; \( J \) is roof end inertia moment, m⁴.

As can be seen from the above two equations (3) and (4), roof bending elastic energy \( U_w \) is proportional to quintic equation of cantilever rock seam length, namely the value of roof weighting step \( L \) is larger, the accumulation energy is greater. Generally, the greater thickness rock is more difficult to cave, and it will form greater value of roof weighting step \( L \). So rock burst in thick and hard roof take places easier compared to thin and soft roof. For the gathered bending elastic energy, the main measure of dissipation energy is to damage roof, to reduce roof weighting step, and then to reduce roof bending elastic energy accumulation.

4. Parameters design of relieving blast in roof

In this paper, Based on the geological conditions of 6303 working face in Jisan Colliery, numerical simulation for in roof was done systematically and effectively in using FLAC³⁰ numerical simulation software, then it analysed relieving shot effects for different blast parameters.
4.1. Influence of relieving shot in roof on abutment pressure

Because sixth coal mining area roof is thick and hard sandstone rock, roof of 6302 working face goaf is not entire breakup, so it made aided crossheading roof of 6303 working face which was near to 6302 working face goaf hang large area, and it also accumulated much stress concentration in aided crossheading roof of 6303 with max value of vertical stress 70.95MPa. Fig.1 is distribution of vertical stress in coal before roof blast.

4.2. Parameters design of relieving shot in roof with numerical simulation

Roof blast damaged roof entirety, then it could form stress relaxation zone of 3m width in roof(Fig.2) and changed mechanical property of original rock. Based on drilling fracture growth degree and relevant data, numerical simulation was done after defining mechanical property of fracture zone[7-9].

Simulation steps: First, the blast deepness 20 m was simulated with four blast angle conditions of 45°, 60°, 75° and 90°. The results showed that stress relaxation effect was better under conditions of 75° and 90° (75° blast hole is operated conveniently in the process of construction). Second, blast angle 75° was simulated with four blast deepness conditions of 10 m, 15 m, 25 m and 30 m.

4.3. Distribution of vertical stress in coal under different blast angle

Fig.3 (a) shows distribution of vertical stress in coal under the blast deepness 20 m about four blast hole angle conditions of 45°, 60°, 75° and 90°. By extracting and analyzing abutment pressure peak of different conditions in Fig 3(a), stress peak declined after carrying out roof burst of different angle in blast hole deepness 20m, for example, 75°, vertical stress peak in coal reached 59.82 MPa, it declined 15.69% (comparing with Fig.1), rock burst danger was reduced. Numerical simulation showed that blast effect was near under blast hole angle 75° and 90°.Thinking that blast hole angle 75° was made conveniently, so this roof blast parameter was chosen in sixth coal mining area in Jisan Colliery.

4.4. Distribution of vertical stress in coal under different blast deepness

Fig.3 (b) shows distribution of vertical stress in coal under the blast hole angle 75° about five blast deepness conditions of 10 m, 15 m, 20 m, 25 m and 30 m.

Through Fig.3(b), in the same blast hole angle under different blast deepness stress peak declined after increasing blast deepness, stress peak declined most in blast deepness 15m, so it proved relieving utilization ratio is highest. The change of stress peak decline ratio was not obvious over blast deepness 25 m.
Fig. 3. Distribution of vertical stress for (a) different blast angle and (b) different blast deepness with different blast parameters.

5. Practice of relieving shot in roof

5.1. Parameters of relieving shot in roof

Top roof bolter and hexagonal hollow steel matching with φ 30.5 mm drill was used to construct project with the blast hole deepness 10–15m, the blast hole space 3.0m with single row layout, and distance 300 mm between blast hole and goaf coal side, and blast hole 75° with horizontal direction toward to goaf (Fig 4). The sealing length was 3–3.5m, then the charge length was 6.0m, and blast was detonated using water gel explosive of mine safety permission and the first section electric detonator of millisecond delay with FMB–200 type exploder. One blast hole used four explosive sticks, and could blast five drillings. Connection type was parallel connection in hole and series connection in inter-porous. The same set of blast hole was constructed at intervals of 10–15 m.

Fig. 4. Sketch map of top blast hole in aided crossheading of 6303 working face

5.2. Test of treating effect

DG80-1 type sight instrument which was invented by China University of Mining & Technology was used to monitor roof blast effect in Jisan Colliery, and electromagnetic emission and drilling cutting method was used to test danger-breaking effect of relieving blast in roof.

5.2.1. Monitoring with sight instrument

Through observation results (Fig 5), rock was damaged in blasting location or near blasting location, and drilling damage was mainly longitudinal direction. Because blast hole space was less-than blast fracture cycle, this made fracture cycle connect with each other. It was proved that blast measures were accurate and suitable. Roof blast damaged hard roof rock above coal wholly and cut roof of 6302 working face goaf off, so accumulated energy was released in roof. In the same time, fracture was formed in roof, then roof was cut off with roof going down in the fracture location. Rock burst danger which was caused by movement of hard rock above coal was reduced.
5.2.2. Effect test with electromagnetic emission

Before roof blast, electromagnetic emission value, over 120 mV, was higher. After roof blast, electromagnetic emission value was lower, as it was showed in Fig 6. By comparing results, after roof blast, the pressure which was caused by roof in coal reduced, in the same time rock burst danger reduced.

![Fig. 6. Electromagnetic emission signals](image1)

![Fig. 7. Coal fines quantity and burst danger](image2)

5.2.3. Effect test in drilling cutting method

Results of coal fines quantity is showed before and after blast in Fig 7. Before blast, coal fines quantity exceeded critical value, especially after drilling 6 m, coal fines quantity became more, which indicated higher stress in coal. After blast, coal fines quantity reduced, so it indicated that stress in coal was changed and burst danger reduced.

6. Conclusions

(1) Thick and hard roof rock is very likely for rock burst to take place. For the gathered bending elastic energy, the main measure of dissipation energy is to damage roof, to reduce roof weighting step, and then to reduce roof bending elastic energy accumulation.

(2) In the same blast deepness, blast effect becomes better when blast hole angle becomes bigger, but blast effect was near under blast hole angle 75° and 90°. In the same blast angle, relieving blast effect becomes better when blast hole deepness becomes deeper, but over blast deepness 25m, roof blast effect becomes not obvious.

(3) For causing rock burst danger by movement of 6303 working face hard rock, good results are achieved by using danger-breaking measures of relieving shot in roof.

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