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Analysis and optimizations on retreating mining measures of rock burst prevention on steeply dipping thick coal seam in deep exploitation

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Abstract

With the reduction of mine reserves in shallow coal-bearing series, the mining proportion of steeply dipping thick coal seam in deep strata is increasingly high. Deep exploitation not only increases the chance rock burst happening in mine, but also there are some difficulties for the stability of corollary equipments in working face in the process of full-seam mining of steeply dipping thick coal seam. 4# coal seam of Huafeng colliery is under the geological condition of steeply dipping thick coal seam in deep mining. In the process of retreating mining, rock burst and stability of equipments always restrict the mine’s production. Through comprehensive analysis of 4# coal seam, including the places of rock burst happened, comprehensive management actions of rock burst and the relevant mining method and so on, found that adopted the exterior entry layout of dislocated strata gateway in the colliery is still inadequate to improve the problem of stability of equipments along coal seam floor. Besides, continuous mining to the east is too long, reduce the mining speed and mining of protective seam are not effective measures, even the occurrence reasons of rock burst. In response to these issues, further proposed the internal entry layout of dislocated strata gateway, through theoretical and experimental analysis, getting that the reform of tunnels arrangement not only improve the stability of mining equipment, but also change the present situation of rock burst of 4# coal seam fundamentally in Huafeng colliery.

Keywords: Deep exploitation; steeply dipping seam; rock burst; stability of equipment; layout of dislocated strata gateway

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Huafeng colliery is mining the No.4 coal seam, whose average thickness is 6.2m, and average inclination is 32°. The current recovery depth of the 1411 working face is -920m - 1000m, taking into account the surface elevation of more than +100 m, so the depth of mining is more than 1000m. The No.4 coal seam mainly applies the top-coal caving method, the machine mined height is 2.3m, while the top caving height is 3.9m, and the coal seam hardness is from 1.5 to 2.5, the coal seam is stable. the relatively gas content is 0.0606 m³/t, the coal-dust explosion index is 35.5%, and the spontaneous combustion time is 3 months, and the working face has a strong burst tendentiousness.

The research at home and abroad shows that 30° -35° is the natural rest angle of the falling rock; when exceeding this angle, the falling roof will be rolling down along the slopes, and form the characteristics that sloping direction of the working face is filling and the upper is hanging in the air. And, when the direct roof is damaged, the downturn will prompt it slide down, thus it will cause the damaged sliding zone spread up in order to make the supporting system be instability. the lower performance completely filling, the central part of the upper filling and impending are showed in [1].Because the mined-out area or mining face was completely filling, the roof is very easy to form stable structure, and has small face pressure, the roadway is easy to maintain. and the huafeng coal mine 4 # seam mining situation can also show, all the lane almost didn't cause the impact pressure. But from another Angle, during coal mining of the mining face, on one side is good, packing degree of mechanical properties is equivalent to the coal pillar to load bearing capacity, three strong. In face, as the recovery of coal mining face down to fall below the impending, so the coal block in the side appears the free surface and provide the conditions occur for the impact pressure. meanwhile, because 4 # coal seam occurrence depth distance is more than kilometers, surface statistical analysis shows that the greater the mining depth is, percussive ground pressure are also more likely to happen. Considering the safety line, when the depth is fewer than 350 m, shock pressure are rarely happened. when the condition is 350m<H≤500m, the impact pressure risk will be gradually increasing. and with the increase of mining depth, the risk of percussive ground pressure increase sharply from the 500 m. In addition, 4 # coal seam, the recovery of shanxi formation belong to the end of the 1410 face, its mining caused by fracture zones will achieve the above the stone box groups, and the village and the bottom of the fissure water pressure group, thus it will cause the confined water penetrate to 4 # mining face. meanwhile, it brings a more serious problem, namely, the loss of water in the group cause the village and the thick conglomerate moving in order to provide sufficient conditions for the percussive ground pressure. In fact, in the early 1990's huafeng coal mines have appeared percussive ground pressure. After 20 years of hard work, the prevention measures in blunt formed a complete system in shock pressure of prevention. but up to now, the 4 # coal seam mining still has the problem of impact pressure.

Therefore, it is sure that the purpose of the research is to improve the equipment stability the angle brings and lower the problem of the incidence when deep mining causes impact pressure.

1. The recovery status of 4# coal

1.1. Work face layout

No.1411 face is being mined currently, thanks to the two lane of the face is layout along the coal seam floor, Figure 1, the two lane are affected by some factors during the mining period, which makes mine become difficulty, including:(1) It is difficult to guarantee the stability of mining equipment, supports become easy to dump, supports and the scraper conveyor also become easy to decline leading to difficult to control; (2) “V” roof becomes more difficulty to support at the upper and lower termination; (3) Scraper conveyor and loader is difficult to lap on the incline; (4) The supporting difficulty is big at the
upper and lower exports of the face; (5) Loading efficiency of the shearing machine is low, and the big block coal is easy to roll.

Therefore, In response to these technical problems, from No.1411 work face use the seam stagger roadway layout, Figure 2. As can be seen from Figure 2, section wind tunnel arranged along the seam roof, wind tunnel arranged along the seam floor, this is typical the seam stagger roadway layout. Taking into account the overlapping relationship between adjacent face, belong to Outward Staggered Disposal. Purpose is to rely on face of the slope from the segment on one side of roof tunnel solve the problem of equipment down. But, as the site lack the necessary technical support, the application of the seam stagger roadway layout still has some shortcoming, Include: (1) Upper termination supporting difficult; (2) Intake airflow drift along the roof seam layout, consider the 6.2m thick coal seam, according to adjacent chute were allowed the maximum 3 of uplift, as shown in the figure that the return airway roof layout is not objective; (3) The relational design found between the number 1412 work face and the face keep 5m wide of section of roadway small pillar along the sloping, in accordance with characteristics of large angle roof caving, it is not considered that rock burst occurred was improved significantly. In addition, the section of the reserved pillars did not reflect the characteristics of the high recovery rate of Split-level roadway layout.

1.2. The preventive treatment related measure and analysis of the rock burst in Huafeng Mine

On the basis of effect goal and space-time range in govern the rock burst, the measure divided in three types: precautionary measure, get rid of dangers measure and protective measure. The first type is strategic or regional measure as: regional forecast of geological power, the reasonable select of the development layout and mining way, nonimpact process of the roof or coalbody in advance etc; the second type is tactical or local measure which aim is get rid of dangers dispose to the formed or possible impact section, included unload drill, induce explode, coal seam unload, water injection etc; the third type
is passivity measure which aim is avoid people hurt or equipment damage when happen small-scale impact. Such as strengthen support, wide lane tunnel. Huafeng Mine adopt prevent impact measure in 1411 mining face on basis of the experience accumulated many years as follows:

1)Forecast of the impact danger area

Because of the movement of the conglomerate and the effect of the periodic weighting, look-ahead 100m extent of the district sublevel entry is the influence area of advance pressure in the working face; the area influenced by the 1410 gob is the impact danger area.

2)prevent impact measure during mining

1)forecast measure include ①electromagnetic radiation monitoring; ②pulverized coal monitoring; ③pressure monitoring; ④microseismicity monitoring; ⑤mining-induced earthquakes monitoring; ⑥rock noise monitoring; ⑦forecast index monitoring

2)forecast measure

When monitor the pulverized coal exceed rule and still exceed rule after blast release;

①happen twice 1-1.5 level rock burst in the same face in one hour;
②happen third 1 level or energe more than 105J rock burst in the same face in two hour;
③monitor mining-induced earthquakes energe more than $6.4 \times 10^6$J/d or monitor microseismicity more than 106J in the same face in two days

(3) release and get rid of dangers dispose measure:

1)process of the release and get rid of dangers dispose:

①the face stop production immediately, all the personnel retreat and put the release and get rid of dangers dispose into practice timely when the two monitor way all indicate would happen impact.
②drilling minor diameter drill in coal blasting release, then adopt pulverized coal monitor the result of the release, if indelibility the danger of impact, adopt major diameter drill release;
③drilling major diameter drill to release, adopt pulverized coal monitoring, electromagnetic radiation, microseismicity monitoring to checkout the release result, the face can be mined when the test index meet the request, otherwise continue to release until the danger of impact remove.

(4) precautionary measure

1)water injection advance in the district sublevel entry
2)release dispose measure in the district sublevel entry
3)control the mining speed, fltting speed is 3-4repeat every during production period, keep the 50-60m in one month, the speed is 1m every, the direction of mining is eastward on the basis of experience accumulate.

The face adopt batch-type mining, reduce the mining rate, strengthen the force piece quality when the danger of impact is enhance, insure the safety

Moreover, Huafeng Mine adopt part of technological reform to prevent the rock burst, include:

1) Remaining of the narrow pillars

Huafeng coal mine is used to remaining narrow pillars between adjacent coal mining face to protect the face from being affected by punched pressure. As mentioned, there are 5 meters wide pillars between adjacent face so that the drift can keep away from the peak value of abutment pressure.

2) Mining of protective seam

The strata above will move and be destroyed after the coal seam is exploited. And then it will form caving zone, water flowing fractured zone and curve subsidence zone from the gob up[3-5]. Usually, at time of mining a group of coal seams, the coal seams are mined from top to bottom to ensure the stability of coal seams which will be further mined. When impact trend coal is being mined , Protective Seam Mining would be used ,which is a way that mine the thinner coal seam first to relief pressure and then mine the thicker coal seam with high gas amount because of the different geology and mining condition. The important factors of Ascending Mining include the distance and the destroying degree of coal seam.
Huafeng coal mine plan to mine coal seam 1# and 6# coal seam first that are regarded as protective coal seam. Coal seam 1# which is 0.82m thick and thinner than other Carboniferous coal seams located above coal seam 4#. The distance between the two seam is 26-57m, at average of 44.88m. Coal seams 6# located under coal seam 4# and distance it for 36-46m at average of 40.35m. The thickness of coal seam 6# is 1.1m. According to table 1, the distance between coal seam 1# and 4# is greater than effective distance. So it is insignificant to regard coal 1# as protective seam. The coal seam 6#, however, meet the requirement of distance of mining of lower protective seams. So it is reasonable to only mine coal seam 6# as the protective seam.

<table>
<thead>
<tr>
<th>The classification of coal seams</th>
<th>Upper protective seams (m)</th>
<th>Lower protective seams (m)</th>
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<tbody>
<tr>
<td>The steeply inclined seams</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>The gently inclined and steep seams</td>
<td>30</td>
<td>80</td>
</tr>
</tbody>
</table>

The essential of the protective seams mining technology is that the coal seams that are protected located in water flowing fractured zone that is formed result from mining of protective seams. According to empirical formula, “three zone” induced by mining coal seam 6# is divided:

- $H_m = \frac{100M}{4.7M+19} \pm 2.2$; $H_L = \frac{100M}{1.6M+3.6} \pm 5.6$
- Descriptions:
  - $H_m$ — The height of caving zone, the unit is meters
  - $H_L$ — The height of water flowing fractured zone, the unit is meters
  - $M$ — The height of mining, the unit is meters
- Results:
  - $H_m = 2.35-6.75m$, $H_L = 14.9-26.12m$.

According to the results, coal seam 6# do not located in the water flowing fractured zone. So it is also insignificant to regard coal 6# as protective seam.

Conclusions:
- The plan of regarding coal 1# and coal 6# as protective seams is insignificant.

(3) Mining face advancing

Through many years of mining experience summary in HuaFeng colliery and in order to avoid the superposition of the formation of abutment pressure peak because of the opposite mining, to determine the number of 1411 work face continue mining in east, until the natural boundary, and driving range over 2000m. However, the colliery has omitted an issue that the increase in thick seam mining space will result in cracks with a high degree of rise, according to field measurement data analysis, in the mining thick, mining face length, roof lithology combination, the influence of mining depth and so on, the maximum height of the hydraulic conductivity fracture zone is 130m when the deep 4# coal seam mining. As mentioned above, which will cause breakthrough of the cracking of overburden, the strong movement of the overlying conglomerate was caused by confined water from the spot crack outflow, it is one of the main factors when rock burst occurred.

Therefore, the reform of stoping technology is not successful on against impact aspect, including to 4# coal there is no practical significance on mining liberated seam, however, the distance of continuous propulsion towards east being too long causes another reason which the rock burst occurs.

Moreover, to a certain extent reducing the advance speed at 1m/d has relaxed the rock burst occurrence, but 4# coal itself has the tendency of spontaneous combustion, so considered about the yield and the security aspects, the technology exists certain limitation too.

2. Optimization and analysis of roadway layout
In summary, although exterior entry layout of dislocated strata gateway layout is being adopted, the above of section tailgate still receives the effect of roof abutment pressure, and large dip angle condition plays the protective function regarding the 4# coal face lower road, but to the mining of the spicing face, because it quickly forms a free surface beside stope, after using the comprehensive against impact technology, the spicing face top gate still has the rock burst phenomenon. At the same time, considering Huafeng mining roadway layout unreasonable, in addition, making full use of the feature that the large dip angle mining brings better condition in back filling the goaf lower part to come up with the optimal suggestion.

![Figure 3](image)

It can be saw form figure 3 that the main optimized measure lies in layout the two roadways in working face to coal-rock roadways. To compare with traditional roadway layout and Huafeng mining exterior entry layout of dislocated strata gateway layout, it has the following advantages:

1. Maintains the high and low export unimpeded and along the bottom mining are unified, having solved the contradiction between them, reduced the triangle bottom coal loss and enhanced the resources recovery ratio;
2. End tail supports could be horizontal arranged in return air drift, being good for the enhancement of the supports and protections system stability;
3. The side of the intake airflow roadway has been achieved the possibility of the chute layout. The length of the slope section is about 15m, and has solved the loss problem of the roadway top on the side of intake airflow roadway. (4) Solved the problem of the lap between conveyor and transfer machine;
4. The coal-rock roadway layout between the two drift could solve the existence of the roadway top-coal caving region, in order to reduce the probability of spontaneous combustion.

Moreover, we could see from the figure that the left side dashed line which is the critical line of section return air drift layout in spicing face, the concrete roadway position selected between the critical dashed line and the goaf; therefore, the protection pillar has been cancelled between the section, and the spicing face top gate layout the underneath previous working surface goaf. Theoretically analysis, the spicing face top gate under the mining process, suffering the effect of abutment pressure smaller, which could avoid the possibility of rock burst to occur on the theory.
3. research on similarity simulation experiment

To fully contrast 1411 working face existing arrangement way with the optimized arrangement, according to the geological condition of 4# coal actual occurrence we carry on the laboratory similarity simulation experiment to analyze, The concrete study is as follows:

(1) the analysis of the situation about the first coalface strata behaviors

As is shown in Figure 4, the first coalface schematic diagram of mining the end, it could be seen from the figure that it more easily forms the joint-dominated structure as a result of the existence of the angle along the working face direction, the fracture angle in the working face lower gangway is bigger than the one in the top gate, and there has been formed the joint-dominated structure at the slope section, playing the protective function to the coal slope section. So we may analyze that if the spicing face layout the section roadway under the slope section, the load bearing decided by the place above joint-dominated structure, what’s more, the right flank line determines the load bearing above roadway probably 10m.

(2) 1411 working face the feature of strata behaviors about exterior entry layout of dislocated strata gateway

As is shown in figure 5, it is Huafeng mining actual working surface arrangement schematic drawing. As a result of the existence of the section coal pillar, two structure have been formed from overlying
collapse strata between the two working faces. Under the process of mining, because of the existing angle, the place above working face top gate suffering the load not only includes influence of mining in working face. Because of the function of large dip angle, firstly on the left side of the coal there presents a free surface. Next, the section coal pillar suffers the load including the weight of overlying strata itself, overlying strataon the both sides of goafs, and the additional load affected on the overlying strata by the joint-dominated structure which formed under goaf in the previous working face. This situation well explains the reason why there still exists the rock burst while using narrow pillar drift in Huafeng coal mining.

(2) the feature of strata behaviors about the continuous work face of internal entry layout of dislocated strata gateway

![Figure 6: The simulation diagram of internal entry layout of dislocated strata gateway](image)

As is shown in figure 6, it is the simulation diagram of internal entry layout of dislocated strata gateway. We can see from the figure that after the spicing face finishing mining, the two neighboring working faces form collapse structure. The roadway suffers the load which is protected by the self-sustaining structure as a result of the triangle coal structure above the section return airway in spicing face that further confirms the advantage of small load to internal entry layout of dislocated strata gateway. In addition, because the two working faces form a whole which results in the height of caving zone increasing, on the one hand, the movement of overlying strata will be undertaken a part by the goaf in the previous working face, on the other hand, the height increasing of the caving zone will reduce the influence of mining dynamic load suffered by the working face. Therefore, it is good for safely mining.

4. Conclusions

In accordance with the related technical difficult problems which are brought by the features of the large dip angle and the deep mining in Huafeng 4# coal, firstly we have analyzed some questions about using exterior entry layout of dislocated strata gateway which is put forward according to working out the problem of the large dip angle. Including the unreality layout of the intake airway along the coal roof, the still question about the head-end support. Besides, using exterior entry layout of dislocated strata gateway layout small pillars does not improve the control of the rock burst.

Next, we analyze its technical measure, thinking that remain supposing the spurs improves the peak value scope of abutment stress effect in spicing face return airway. But there is no actual meaning of
mining liberated seam to 4# coal. What’s more, the overlength of continuous propulsion to the eastwards creates the reason of the rock burst occurs. Reducing the advancement speed relaxes the impact rock burst occurrence to a certain extent, but it is not good for realizing the coal production achievement. In addition, it increases the possibility of the spontaneous combustion.

Based on this, further proposed using the way of stagger arrangement roadway layout, thinking that makes the following progress such as the high and low export is unimpeded and realizes the penetration to mining along the coal bottom, it reduces the triangle bottom coal loss and enhances the resources recovery ratio; What’s more, the side of the intake airflow roadway has been achieved the possibility of the chute layout. The length of the slope section is about 15m, and has solved the loss problem of the roadway top on the side of intake airflow roadway. And the coal-rock roadway layout between the two drift could solve the existence of the roadway top-coal caving region, in order to reduce the probability of spontaneous combustion.

At the same time it has determined the critical range for the layout of splicing face return airway. Under the splicing face mining, this place will be under the protective status of the previous working face goaf with collapse remnant back filling. Therefore, theoretically speaking, the splicing face top gate has the ability to completely protecting from the possibility of the rock burst. According to this phenomenon, similarity simulation experiment has been conducted to analyze the rock burst phenomenon. We obtain the optimal roadway after the experiment. Firstly the splicing face top gate only suffers the weight of collapse remnant, next, the neighboring working face forms a whole as well as the increasing height of related collapse zone, will improve the influence of this working face by conglomerate movement. The working face suffers the dead load primarily.

References


