Mining pressure analysis and accident prevention on deep working face

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Abstract: In recent years, with the increasing depth of coal mines, mining pressure accidents impose a serious threat to mining safety. Through the observation and analysis of the mining pressure of the 11301 fully-mechanized caving working face in Zhaolou Coal Mine. In the paper, the main factors affecting the mining pressure of deep working faces were identified, and combined the existing methods for selection of fully-mechanized supports and roof management technology, aiming to prevent mining pressure accidents in deep working face.

1. Experimental system
The 11301 working face of Zhaolou Coal Mine is the first working face of the 11th mining district with a depth of 946.7~981.2 m. The working face has a length of 503 m, a slope length of 190 m, an average thickness of 6.5 m in coal seam and a dip angle of 2~8°. The coal seam structure is complex. The thickness of the main roof is 24.1~25.7 m. It is grayish white sandstone. The composition is mainly quartz, followed by feldspar, localized fissures, equal grain structure, massive structure and near horizontal bedding, part of the main roof is coarse sandstone, whose coefficient of hardness is 7.1. The immediate roof thickness is 0~8.3 m, and the black mudstone is relatively pure. It contains a small amount of sandy and plant clastic fossils, and the coal line is interposed, whose coefficient of hardness is 4. The distribution of the top and floor is shown in Figure 1. There are 5 faults in the working face, including 2 faults with a drop of 5~10 m and 3 faults with a drop less than 5 m.

2. The law of mining pressure in 11301 working face
The "cross measurement method" and the roof separation indicator were used to observe the deformation of the surrounding rock during the mining, and the law of mining pressure behavior of stope and roadway was revealed[1]. Multiple sets of pressure step parameters were obtained by observing statistical data (table 1).

| Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------|---|---|---|---|---|---|---|---|---|----|
| Step (m) | 19.5 | 17.4 | 17.1 | 15.9 | 15 | 21.2 | 22.2 | 18.1 | 20 | 24.6 |

| Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------|---|---|---|---|---|---|---|---|---|----|
| Step (m) | 18 | 23.5 | 22 | 24.5 | 24.1 | 26 | 18.6 | 21.7 | 18 | 20 |

Through statistics, the periodic weighting in the 11301 working face is 15~26 m, with an average of 20.3 m.
Grayish white sandstone, composed mainly of quartz, followed by feldspar. Contains a large number of argillaceous inclusions, the grain size is gradually thicker from top to bottom. The lower part contains a small amount of coal wire, and the local development is cracked and unfilled. Fine sandstone interlayers are visible in local locations.

Gray-black mudstone, relatively pure, contains a large number of plant fossils and pyrite crystals, a small number of cracks, unfilled, broken, staggered fracture.

Grayish white sandstone, composed mainly of quartz, followed by feldspar. Contains a large number of argillaceous inclusions, the grain size is gradually thicker from top to bottom. The lower part contains a small amount of coal wire, and the local development is cracked and unfilled. Fine sandstone interlayers are visible in local locations. The local location is coarse sandstone, the mineral composition is mainly quartz, and the mud is cemented.

Black mudstone, relatively pure, partially containing a small amount of sand and plant fossils, containing coal lines.

Black, bright coal dominated, dark coal followed. Blocky, harder, endogenous fissure development, filling calcite veins, containing a small amount of pyrite grains, angular or staggered fractures.

Gray-white fine sandstone and gray-black siltstone interbed, the upper part is mainly fine sandstone, the lower part is mainly siltstone, the fine sandstone is mainly composed of quartz, followed by feldspar, localized tensile cracks, filling calcite, local core fracture, RQD value is about 55%.

Figure 1. Roof and floor stratigraphic histogram

3. Main factors affecting the mining pressure in working face

The main factors affecting the mining pressure of working face include geological factors, mining height, working face advancing speed, mining depth and coal seam dip[2-6].

3.1. Geological factors

The main factor affecting the mining pressure of working face is the nature of surrounding rock. The geological factors are naturally formed and constant.

3.1.1 Roof lithology. The roof of the working face generally includes pseudo roof, immediate roof and main roof. The stability of the roof has a significant impact on the mining pressure of working face. The observed result showed that the mechanical properties of the rock played a key role for mining pressure. Rocks vary in strength due to differences in rock density, composition, and particle size. The higher the strength of the rock, the more obvious the mine pressure appears. During the first weighting of the 11301 working face, because the roof in the middle of the working face is fine sandstone, its density is higher. The rock on the roof in the entry contains argillaceous sandstone. Therefore, during the first weighting of the working face, the roof in the entry fell off in time, while the middle roof did
not fall off. The hydraulic support appeared a large number of relief valve open phenomenon in the middle of the working face

3.1.2 Water content of the roof. Any rock has water absorbability, and the strength of rock will deteriorate once it meets water. The measurement showed that the 8th and 9th periodic weighting of the 11301 working face were in the water-bearing area of roof. Although roof of the working face was medium-fine sandstone, the periodic weighting step was relatively small due to the influence of the water.

3.1.3 Development of joint fissure. In general, rocks with faults and fissures are relatively broken, which directly affects the strength of the rock. Such a roof is prone to fall off, thereby releasing part of the mining pressure and allowing it to be moderated.

3.1.4 Impact of key layers on rock movement. Coal-bearing strata are composed of multiple layers, of which we refer to the rock layers that play a major role in rock mass activity as key layers. The collapse of the immediate roof generally does not affect the ground surface subsidence, and once the key layer has cracks, fractures, and rotational instability, the ground will sink. The key layer also has a significant impact on the pressure of the mining layer. Generally speaking, the initial periodic weighting steps are lower than the average value, according to the periodic weighting analysis of the working face. This is because the periodic weighting of the working face and the pressure of the first few cycles are only the collapse of the main roof. As the main roof collapses, the key layer will undergo crack fracture, and its force will be applied to the main roof rock. The periodic weighting steps of the 11301 working face in the first few cycles were relatively small, and their performances were relatively strong. Before and after the working face advanced a distance equivalent of its own length, the key layer would be broken for the first time. This period was the most obvious stage of mine pressure in the working face. Many mining pressure accidents occurred during this period. The periodic collapse of the key layer will be manifested in the periodicity of the cycle step. The data showed that the cycle of the working face is cyclically changed. It is generally believed that the period in which the period step is small is the key layer fracture stage.

3.2. Height of working face
Under certain geological conditions, mining height is one of the most important factors affecting the damage of overlying strata. It is well known that the higher the mining height, the larger the space generated, which inevitably leads to the more serious damage to overlying strata. It was found from the field observation that when the mining height was relatively small, there would be less rib spalling in the working face, and the roof was relatively complete when the mining height was high, indicating that the low mining height had little effect on the damage of the overlying strata. According to the measurement of Huainan mining area, a single coal seam or the first layer of thick coal seam was mining, the mining height was proportional to the total thickness of the caving zone and the fracture zone.

3.3. Advancement speed of working face
The faster the working face advances, the smaller the subsidence of the roof, the faster the sinking speed of the roof, and the more obvious the mine pressure appears. However, only under the condition that the working face advancement speed is relatively slow, and the speed of the working face is accelerated, the condition of the roof of the working face will be improved. When the advancement speed of the working face is increased to a certain extent, the variation of subsidence will gradually be stable, so it is impossible to eliminate the pressure of roof.
3.4. Mining depth
The mining depth directly affects the magnitude of the original rock stress, and the impact on the roadway may be obvious. Therefore, for a mine where there is a risk of rock burst, as the depth increases, the number and intensity of rock burst will increase significantly[7]. However, the influence of mining depth on the pressure of the roof of the working face is not prominent, so the mine pressure is not obvious, especially the impact on the roof subsidence. The deflection of the roof of the working face and the load of the support are related to the structure of the fracture zone, so it should be determined mainly by the mining height, the mechanical properties of the roof and the thickness.

As the depth of picking increases, the bearing pressure will inevitably increase, resulting in an increase in the probability of the coal wall and the bottom plate bulging, which may also result in an increase in the support load.

According to the geological conditions of Zhaolou Coal Mine: the strength of hydraulic support support is checked. Calculated according to the volumetric method:

\[ P = H \times S \times \gamma (Q + 1) \times 10 \]

where \( P \) indicates work resistance force for the support; \( H \) indicates the height of caving zone in the goaf; \( \gamma \) indicates unit weight of overlying strata; \( Q \) indicates dynamic load coefficient; \( S \) indicates support area.

The work resistance force was calculated by actual mine parameter, \( P = 9196.32 \) kN, that is, the reasonable working resistance force of the working face is 9196.32 kN.

Considering that the Zhaolou coal mine is buried deep, the bottom plane bulging may increase the support load. Through the measurement, the 11301 working face is selected with a 12000 kN hydraulic support to achieve effective support for the roof in several stages where the mine pressure appears obvious.

3.5. Coal seam dip
The dip angle of coal seam has a great influence on the mine pressure on the working face. The actual observation shows that the larger the dip angle of the coal seam, the smaller the subsidence of the roof. That is to say, the amount of roof sinking of the near horizontal working surface is much larger than that of the inclined and steeply inclined working surface. The coal seam of Zhaolou Coal Mine is relatively flat. The coal seam of 11301 working face is 2~8°. The roof is all managed by the slumping methods. The dip angle of coal seam has obvious influence on the mining pressure of working face.

4. Prevention and control of mine pressure accidents in working face
The roof collapse accident of working face can be divided into partial roof collapse and large-area roof collapse according to the size of caving area; According to the mechanical factors, it can be divided into the compression type, the skimmer type and the push type[8,9].

4.1. Prevention and control of partial roof collapse in working face
In the roof accident, partial roof collapse is one of the accidents that have not been paid much attention to. The fundamental cause is that it has no obvious sign, but experience tells us that as long as you look closely, such as the sound of the coal wall and rib spalling.

Most of the partial roof collapse accidents caused by human. In the 11301 working face production process, there were mainly two partial roof collapse. The first part is due to the impact of the fault, the range of supports 29~44# appears collapse phenomenon, the main reason is that the supports 20~50# were not keeping up with the working face in time, therefore the coal wall is pressed and the chip is leaking under the pressure of the square pressure and the periodic pressure.

The second part is that the roof was broken, which makes the supports were difficult to move. The main reason is that when the machine was fall behind working face and the roof was broken, the H-shaped steel beam was not used to maintain the roof in time. By summarizing, the main measurements for controlling the roof of the working face as following:
(1) To strengthen the initial support of the supports, avoid the phenomenon of The equipment falls behind the working face, ensure the quality requirements of the “three straight and two flats”.
(2) Improve the technical level and operational level of employees, reasonably select the type of support, and do a good job of monitoring.

4.2 Prevention and control of large-area roof collapse in working face

In the advancement of the working face, the goaf is not filled full by the caving zone, and the stress on the working face is concentrated when the periodic weighting is coming in main roof. In this case, it is easy to have a large-area roof collapse accident. Large-area roof collapse accidents have obvious signs, such as the sound of cracking on the roof, increased pressure on the working face, and coal became soft. The danger of a large-area roof collapse accident on the working face is quite serious, which directly affects the safety of workers and caused huge economic losses.

Because of the seriousness of the large-area roof collapse accident on the working face, it is necessary to do prevention and control works. The following work should be done to prevent the large-area roof accidents in the working face:
(1) Improve the support strength and ensure the stability of the bracket;
(2) Do a good job in monitoring and supervision;
(3) Strictly control the mining height.

4.3 Rock burst prevention

Rock burst is the most serious accident in deep working face. In recent years, as the mining depth increased year by year, the danger of rock burst will become increasingly serious. At present, there are many mechanisms of rock burst, among which strength theory, energy theory and impact tendency theory are basic theories. According to the mechanism, there are mainly the following types of pressure relief measures[10,11]:
(1) Coal seam relieves pressure by blasting technology. This method has good adaptability to various geological conditions, simple construction, convenient operation, flexible construction time and location. Therefore, the technology has been widely applied and controlled by rock burst.
(2) Coal seam water injection technology.
(3) Roof-cutting by deep hole blasting technology. According to the key layer theory, the rock burst is often caused by the change of the stress of a layer of the strata. This layer of rock is the key layer. The key layer is blasted through the deep hole, and the stress is changed in advance so that the stress concentration of the key layer cannot be built or minimized, thereby avoiding the occurrence of rock burst. When the Nantun Coal Mine mined the “island” working face, it was affected by the rock burst. In the square area of working face, the deep hole blasting of the key layer is carried out in advance to relieve the pressure.
(4) Pressure relief by drilling technology. The technology is implemented before the high stress concentration or rock burst are formed in the coal seam, so that the coal seam no longer has the condition of forming high stress concentration, thereby avoiding the occurrence of rock burst.

5. Conclusion

The roof accident is one of the “five major disasters” in the coal mine. The strata pressure behavior of the deep working face is related to the geological factors, the height of the working face, the advancement speed, the mining depth and the dip of the coal seam. Through the above analysis, the causes for accidents on the working face of a deep mine, and the prevention measures of roof accidents were summarized. Further discussion is needed as following:
(1) The technical equipment level of coal mining needs to be further improved, including increasing the capacity of the support, and apply new support methods.
(2) The monitoring level and technology of the roof needs to be further improved, and then timely forecast possible disaster and accidents.
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