Analysis of underground pressure in fully mechanized top coal caving mining face in greater inclined and weak coal seam.

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Abstract. Taking Zhaogezhuang Coal Mine's fully mechanized top coal caving test face as the engineering background, through real-time monitoring of the working resistance of the support and the displacement of the top coal and the old roof, the top coal and roof movements at the high dip angle were studied and analysed. The law and the falling characteristics, the initial pressure and the periodic step and pressure strength of the working face are analysed, and the changes and distribution characteristics of the working face pressure along the slope are analysed. Through the research results of this paper, it provides scientific basis for the reasonable parameter design and formulation of the large-inclined working face of the mine, subsequent production process and equipment improvement, and provides technical reference for the mining of similar working faces.

1. Introduction
The current development level of high-inclined coal seams is far lower than that of gently inclined coal seams, and there are a series of technical problems to be solved. Therefore, it is very necessary and urgent to study and master the law and characteristics of the appearance of the rock pressure in the coal seam with large inclination, in order to improve the production efficiency of the working face and ensure the safety of the working face.

2. Paper project background
The coal mine of Zhao Gezhuang's fully mechanized top coal caving face has a length of 526m and a tendency of 120m. The working face is mining NO.12 coal seam, the coal seam inclination angle is 24-35 °, and the average inclination angle is 28 °, which belongs to the high-inclined coal seam mining. The thickness of the coal seam is 9.12-14.27m, with an average thickness of 10.69m. Joints and fissures are developed, and the coal quality is soft. The basic top is dark gray siltstone, with an average thickness of 5.62m, with muddy cementation and dense gray-brown streaks. The direct top is a black saprolite clay rock, with an average thickness of 5.46m, brown oily streaks, shell-shaped fractures, and brittle. Fragile, containing pyrite nodules, the floor is dark gray siltstone, with an average thickness of 2.24m, argillaceous cement, containing a large number of plant root fossils, the histogram of the working surface is shown in Figure 1.
3. Analysis of working pressure

With the help of electronic pressure gauge, we can continuously observe the load of the hydraulic support column, calculate the initial support force, working resistance, time-weighted average working resistance and support strength of the support, etc.; also we can calculate the working characteristic curve of the support, that is, the type of relationship between statistical resistance and time. The percentages of each type in the pressure-time (P-T) curve at different time periods. Based on this, the nature and size of the roof support pressure of the fully mechanized caving face, the support status of the support at each time period, and the adaptability of the support to the top coal and roof are analyzed.

3.1. The deployment of the pressure measuring point on working face

The pressure measuring points on the working face are arranged along the vertical direction, and the upper, middle and lower three measuring lines are respectively arranged in group 5, group 30, and group 55 (see Figure 2). A double-port pressure is installed on the support for measuring the line. The recorder records the pressure of the front and rear columns of the stent, respectively. Through statistical analysis of the stored data, the relationship curves of the initial support force, support resistance and time of the hydraulic support on each survey line are obtained.

3.2. The distance between of two appearances of mainly roof pressure

Using the number of observation cycles (N), the date of observation (day / month), and the distance to the starting point of observation (L) as the abscissa, the initial support force of the cycle, the resistance at the end of the cycle, and the time-weighted average resistance as the ordinate. The distribution curve of the resistance along the advancing direction of the working surface is shown in Figs. 3, 4, and 5.

As shown in Figure 3, Figure 4, and Figure 5, during the observation period, the working face experienced a total of 4-5 cycles of pressure, and the ratio of the average value of the support resistance before and after the previous pressure is 1.2 to 1.4, which belongs to Fully mechanized caving face with obvious pressure is shown in Table 1 for the step distance and parameters.
Table 1 The step and strength of the old top pressure on the working face

| Pressure nature and frequency | Survey line | Initial pressure step (average, m) | Periodic weighting step (average, m) |
|------------------------------|-------------|------------------------------------|-------------------------------------|
| Periodic pressure of main roof | 5 | 5 | 24 | 9 |
|                              | 4 | 30 | 24 | 11 |
|                              | 4 | 55 | 25 | 11 |
| average                      | 24.3 | 10.3 |

3.3. Main roof compressive strength

The measured data are shown in Table 2, Table 3, and Table 4.

Table 2 Measured statistics of the initial supporting force of the test face support (KN/unit)

| NO. | Average | Variance | Maximum | Ratio of average value to rated value (%) |
|-----|---------|----------|---------|------------------------------------------|
| 5   | 1506.1  | 360.4    | 2122.8  | 47.1                                     |
| 30  | 1236.7  | 408.4    | 2012.3  | 38.7                                     |
| 55  | 1060.1  | 449.2    | 1680    | 33.2                                     |
| Average | 1267.7  | 406      | 1938.4  | 39.6                                     |

Table 3 Measured statistics of the end resistance of the support on the test face (KN/unit)

| NO. | Average | Variance | Maximum | Ratio of average value to rated value (%) |
|-----|---------|----------|---------|------------------------------------------|
| 5   | 2526.8  | 696.2    | 4120.3  | 63.2                                     |
| 30  | 2065.3  | 815.2    | 4001.6  | 51.6                                     |
| 55  | 1766.4  | 868.4    | 3626.5  | 44.2                                     |
| Average | 2119.5  | 793.3    | 3464.4  | 53                                       |

Table 4 Measurement statistics of weighted working resistance of bracket on test face (KN/unit)

| NO. | Average | Variance | Maximum | Ratio of average value to rated value (%) |
|-----|---------|----------|---------|------------------------------------------|
| 5   | 2319.5  | 570.5    | 3803.4  | 58                                       |
| 30  | 2056    | 688.1    | 3184.6  | 51.4                                     |
| 55  | 1764.4  | 744.4    | 3140    | 44.1                                     |
| Average | 2046.6  | 667.7    | 3184.4  | 51.2                                     |

The Analysis of the data in the above three Tables leads to the following conclusions:

1. The average value of the measured initial supporting force is 1267.7KN / frame, and the ratio of the average value of the initial supporting force to the rated initial supporting force (3196KN / frame) is 39.6%; the maximum initial supporting force is 2122.8KN / frame (measured), accounting for 66.4% of the rated initial support force. From the measured data, it can be seen that the rated initial supporting force of the bracket can well meet the requirements.

2. The average value of the measured working resistance is 2119.5KN / frame, and the ratio of the measured value (average value) of the maximum working resistance to the rated working resistance
(4000KN / frame) is 53%; only the maximum working resistance exceeds the rated working resistance when just observed. Which only accounts for 1% of the measured cycle, the maximum is 4120.3KN / frame, which exceeds the rated working resistance of 120.3KN / frame. This shows that the bracket can fully support the top plate in this working surface.

(3) The time weighted average is 2046.6KN / frame, and the time weighted average working resistance is equivalent to 51.2% of the rated working resistance (4000KN / frame). Its maximum value is 3803.4KN / frame, which is equivalent to 95.1% of the rated working resistance. From this point of view, the application of such supports in this coal mining face is relatively rich.

(4) The measured dynamic pressure coefficient of the working surface is 1.2 to 1.4, and the pressure is obvious.

3.4. Analysis of the appearance of the pressure in the inclined direction
Analysing the above statistical data, the support load of the test working surface, including the initial support force of the support, the time-weighted average working resistance and the end-of-cycle resistance, is unevenly distributed along the tilt direction. Small. The lower bracket is only about 76% of the middle and upper brackets. Moreover, according to the actual observation of the support force of the working face support, although the support at the middle and lower faces of the working face behaved when the top coal was first pressed, the performance was not obvious when the roof was pressed. The reason for this is that when the working face was initially advanced, there was less vermiculite falling in the goaf, the lower part of the working face was not fully filled, and the roof pressure could still be transmitted to the working face and its support. When the working face was advanced to a certain distance In particular, after the direct roof collapse, the vermiculite and floating coal in the goaf began to increase, and part of it fell and filled the lower part of the working face, making the roof activity at the lower part of the working face less active. In the subsequent appearance of the mine pressure, the performance was not very violent. Even when the old top was pressed for the first time, it did not have the same obvious increase in pressure as the upper and middle working faces.

4. The principle of Roof coal and roof moving law

4.1. deployment of observation station
On the basis of comprehensive test face histogram, the return air lane with two station (station I and station II), two station spacing of 30 m, every station dozen three deep hole base (deep hole end at main roof and immediate roof, top-coal), a total 6 points, specific arrangement design as shown in Figure 6, 7 and shown in Table 5. The design parameters of the two stations are the same. The spatial relationship and control parameters of the deep base hole are shown in Figure 8 and Table 5.
FIG 8 Schematic diagram of the spatial geometric state of deep foundation holes

Table 5  Geometric parameter values of borehole design (construction) for deep base point observation at Stations I and II

| parameter  | station I | station II |
|------------|-----------|-----------|
|            | 1 | 2 | 3 | 1 | 2 | 3 |
| L$_S$ (m)  | 36.82 | 35.48 | 35.1 | 36.82 | 35.48 | 35.1 |
| $\alpha$ (°) | 19.8 | 12.55 | 9.27 | 19.8 | 12.55 | 9.27 |
| $\beta$ (°) | 30 | 30 | 30 | 30 | 30 | 30 |
| $\gamma$ (°) | 24 | 24 | 24 | 24 | 24 | 24 |
| L$_1$ (m)  | 17.32 | 17.32 | 17.32 | 17.32 | 17.32 | 17.32 |
| L$_2$ (m)  | 30 | 30 | 30 | 30 | 30 | 30 |
| h$_0$ (m)  | 12.47 | 7.71 | 5.65 | 12.47 | 7.71 | 5.65 |
| h$_1$ (m)  | 2.1 | 1.8 | 1.5 | 2.1 | 1.8 | 1.5 |

L$_1$—The horizontal length from the opening to the deep base point parallel to the direction of the return air lane;
L$_S$—Actual wire length from hole to deep base point;
L$_2$—The horizontal length perpendicular to the axis of the return airway from the opening to the deep base point;
h$_0$—Vertical height from orifice to deep base point;
h$\hat{}$—Vertical height from coal floor to deep base point;
a—Elevation angle of deep foundation hole;
$\beta$—Horizontal angle between deep foundation hole and return air duct;
$\gamma$—Seam inclination;
The station is arranged in the chamber on the side of the working face of the auxiliary roadway, with a depth of 1.5-2.0m and a height of 2.2-2.5m.

The method of installing anchoring device can be used to fix the deep base point in the hole. Anchoring device is composed of ordinary steel tube, spring steel sheet and fine steel wire. The length of the steel pipe is 100 ~ 120mm, and the outer diameter is slightly smaller than the inner diameter of the drill hole. The steel sheet is 90×15×1.2mm (length × width × thickness) and is fixed on the outer wall of the steel tube with double row screws. In order to ensure that the anchor is fixed reliably in the drilling hole, the spring steel pieces should have certain rigidity, and the upper and lower two layers are installed symmetrically 8 pieces, 4 pieces for each layer. A small hole is drilled along the bottom of the steel sheet, which is used to pass through and fix the steel wire with a diameter of 0.5 ~ 1mm.
4.2. Displacement observation and analysis of top coal and top plate

According to the above arrangement plan of measuring points, the measuring points are arranged and monitored in real time. The measurement results are shown in FIG. 9 and FIG. 10.

Note: L - horizontal distance between the measuring point and the coal wall of the working face, unit m, where positive value means that the measuring point is in front of the coal wall of the working face, and negative value means that the measuring point is in the goaf direction.

The Station I at the working face in front of 30 m, begin to produce trace amounts of goaf direction displacement of the top-coal is parallel to the working face is formed in the top-coal fissure, and then the cumulative displacement of the top-coal is slowly increase with working face is close to (the expansion and development of cracks), when the working face advancing to 2 m measuring point and top-coal displacement increased significantly, when the working face advancing to the points below, displacement began to increase sharply, explain here has broken into medium and the top-coal caving. Ahead of the coal wall coal point, in the displacement of the top roof pressure, the eme inner from 25 m away from the front face is the level of open fracture, and continually development, makes the top-coal begin to move horizontally, goaf direction until the working face in front of the 2 m place, under the effect of sustained repeatedly, the broken caused significant increase in the vertical displacement of the gateway, in that the vertical displacement increases further, the final at the working face of coal wall after losing support bottom-up caving step by step, and to working face coal mouth direction released at the end of the bracket.

According to the analysis of the total displacement and displacement change rate of the top coal, the top coal produces macroscopic failure in the range of about 2m in front of the coal wall, and collapses in the upper part of the support behind the coal wall, with the collapse Angle exceeding 60°, while the top coal's collapse Angle may reach more than 100° in the period of pressure.

With the advancement of the working surface, the displacement of the main roof gradually increased. At about 10m, there was a significant displacement, indicating that the main roof broke here; then the displacement increased suddenly, indicating that the main roof became a staged collapse fracture. Affected by mining, the peak value of the leading bearing pressure appears 10m behind the coal wall of the working face. Although the dynamic pressure coefficient is not large, the pressure is obviously periodic. According to the observation and analysis of the mining pressure on the working face, it can be seen that the support load shows that the support resistance and subsidence of the support changes periodically every 8 ~ 12m when the working face is advanced. An instability occurs, resulting in a significant cycle of pressure on the working face. Therefore, from the observation of the working pressure of the test face and the observation of the displacement of the top coal and the roof, it can be concluded that the cycle of the test face is 8 to 12 m, with an average of 10 m.

5. Conclusion

In this paper, through the on-site measurement and analysis of the support working resistance, top coal and roof displacement of the first mining test face in Zhaogezhuang Mine, the mining pressure manifestation rules and characteristics of the large-inclined working face are obtained, which are
reasonable techniques for the working face. The parameter design and formulation provide a reliable technical basis for the improvement of the technology and equipment selection of subsequent working faces, and provide a reference for the mining of similar working faces.

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