Applied Research of Combined Sliding Support in Complex Roof Working Face

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Abstract. It is one of the key issues to be solved urgently in the process of sustainable development of coal mine, which is the safe and efficient recovery of coal resources in the complex roof irregular and scattered zone and the complex roof of Jixi Mining Group Shenghe Coal Mine. In order to solve this problem, the mine carried out research on the applicability of combined sliding support under complex and difficult coal seam conditions. Using the combination of theoretical calculation and field data acquisition and analysis, the stability and working resistance of the combined sliding support under the conditions of the coal seam are studied. The research shows that under different roof conditions, the front and rear pillars of the combined sliding support has different pressure, the working resistance of the support does not exceed its rated working resistance, and the adaptability to the direct roof crushing is more serious. The combined sliding support is generally adapted to the geological conditions of the mine production, and can meet the mine production demand and achieve certain technical and economic benefits.

1. Introduction

For the medium-thick coal seams under simple conditions, the full-scale coal mining method and technology have been successfully applied in many mining areas, especially the solution of some key theoretical problems and the development and application of complete sets of equipment such as large mining height hydraulic supports, which greatly promotes the progress of mining technology. Researchers at home and abroad have conducted in-depth research on the full mining method and technology of fully mechanized coal mining face, especially the innovation of hydraulic support for coal face and its on-site application progress, which greatly promoted the development of coal mining technology [1-2]. While the exploitation of coal resources continues, the safe and effective mining of coal resources in some irregular and scattered zone is put on the agenda [3-4].

From the perspective of safety, improvement of resource recovery rate and production practice experience, conventionally-mechanized coal mining technology, blast-mining technology and slicing mining technology using large mining height single hydraulic props can not solve the requirements of safety, high production and high efficiency, but the full-mechanized mining technology brings matters such as high cost and cumbersome work surface movements restrict its promotion and application in irregular and scattered zone coal resource. The complex sliding support not only has the flexibility of the single pillar, but also has the safety and reliability of the hydraulic support. It has obvious advantages in terms of technology and economy, and has been successfully applied in some coal mine. Some scholars have conducted in-depth research on the coal seam pressure law and the matching hydraulic supports [5-8], but under the condition of composite roof, the research on the use of
2. Working place situation
There are a large number of irregular and corner sporadic coal blocks in the Didaoshenghe coal mine of Jixi Mining Group. The six-panel working face of coal mine has a strike length of 270m, an inclined length of 150m with an average thickness of 1.6m, and an average inclination of 24°. The coal seam development is relatively stable. The roof of the working face is a composite roof, the lithology is soft, the degree of partial fracture is high, and the mine pressure is severe. The false roof of coal seam is interbedded with shale and carbon-bearing shale, with a thickness of 0.6m, the direct roof is sand shale, the thickness is 1.2m, the main roof is sandstone, and the thickness is 20m. The working face can not adapt to conventionally-mechanized coal mining technology, blast-mining technology for the high-yield and high-efficiency of the mine, and the comprehensive mechanized mining cost is high, and the working face moves frequently. Compared with the fully mechanized mining support, the combined sliding support has the advantages of less connecting parts, small volume, light weight, easy operation, convenient working face, low price, etc. Compared with the single hydraulic prop, the combined sliding support can be moved. The automation of the frame increases the degree of mechanization, which reduces the manual labor of the workers, guarantees the safe production environment, and also increases the production of the work surface.

3. Working face pressure calculation

3.1. Working face roof pressure
The mine gob is treated by full caving method. The maximum and minimum roof control distances of the working face are 3.7m and 3.1m respectively, the roof caving distance is 0.6m, and the end face distance is 0.2-0.3m. When the working face soft slant is more than 5m long and the suspension roof is over 2m, the forced roof caving is adopted. The support strength of the bracket is calculated by the formula (1):

\[ p = q_1 + q_2 = h\rho g + \frac{M}{(K-1)\cos\alpha}\rho g = n \frac{M}{(K-1)\cos\alpha}\rho g \]  \hspace{1cm} (1)

Where \( q_1 \) is the main roof pressure; \( q_2 \) is the immediate roof pressure; \( M \) is the mining height, which is 1.6 m; \( K \) is the rock swell factor, which is 1.24; \( \alpha \) is the coal seam dip angle, which is 25°; \( \rho \) is the rock the average density is 2.5t/m³; \( h \) is the main roof thickness and \( n \) is the load-increasing coefficient, which is 2. Calculated \( p = 0.38 \) MPa.

3.2. Combined sliding support pressure calculation
The virtual prototype model of the ZH1600/15/26B combined sliding support is shown in Figure 1. The main technical parameters are shown in Table 1. The working resistance of each set of brackets is 1600kN, the initial supporting force is 570-760kN, and the spacing of the racks is 1.0m. The supporting strength \( p' \) is calculated by formula 2:

\[ P' = F \cdot S = F \cdot (L \times B) \]  \hspace{1cm} (2)

Where \( F \) is the working resistance of the bracket; \( S \) is the control area of the bracket; \( L \) is the minimum topping distance, which is 3.0 m; \( B \) is the spacing of the bracket. The calculated support strength \( p' \) is 0.52MPa, which shows that the support of working face adopts the support requirements.
3.3. Stability analysis of support
There is no cantilever roof beam support of the bracket. The theoretical formula of the moment and the actual field pressure measurement show that the pressure of the front pillar is more than 90% of the total pressure of the roof, and less than 10% of the pillars in the rear row. There is cantilever roof beam support of the bracket. The theoretical formula of the moment and the actual field pressure measurement show that the force of the front and rear pillars is obviously improved, and the pressure of the front pillar of the support is reduced to about 50% of the total pressure. Therefore, in the actual production process, the temporary strut of the combined sliding support front extension beam should be set to optimize the stress distribution and ensure the stability of the support.

4. Engineering application

4.1. Pressure observation of working face
The working face was observed continuously for 5 periodic weight. The result is that the first
weighting interval of the main roof is 15.6m, and the first weighting interval is 6-8m. During the initial pressure of the main roof, the working resistance of the bracket reaches 1426KN, which is less than the maximum working resistance of the bracket is 1600KN. The average support strength is 240KN/m², the working resistance of the bracket does not exceed its rated working resistance, and the distribution of the bracket resistance is shown in Figure 3. The main pressure on the support is the generated by immediate roof collapse and main roof sinking. During the field use, it was found that the combination sliding support effect under different conditions immediate roof was significantly different. In the flat area of the roof, the working condition of the bracket is good, effectively controlling the roof fall and the coal rib spalling, ensuring the safe mining of the working face, reducing the labor intensity of the workers and the supporting effect is obvious. On the contrary, in the broken section of the composite roof, the integrity of the roof is poor, the possibility of roof topping increases, the bite frame between the support, the damage of the hydraulic pipeline, and the collapse of the pillars during the pressure relief, which brings certain difficulties to the mining work. The support is not fully adaptable.

4.2. Working face pressure rules

(1) When the composite roof is fully harvested, the front pillar of the support carries a large roof area, and the load pressure is higher than that of the rear pillar; in the severe fracture of the composite roof, the rear pillar of the support. The resistance is higher than the front row, because the broken roof deformation compacts the broken top coal above the rear pillars, which in turn carries most of the force.

(2) The working surface has repeatedly measured the cycle pressure data to show that compared with the non-pressure period, the pressure of each row of pillars has increased to different extents, and the average resistance of the rear pillars is larger than that of the front pillars. The analysis shows that most of the force on the support during the main roof fracture process is applied to the back beam through the hinge point of the support end, thus increasing the resistance of the back beam support and increasing the speed.

(3) When the composite roof is periodically collapsed, the immediate roof and the false roof should produce large deformation to continue to exert the effect on the support. The deformation of the immediate roof and the false roof will absorb the energy of the part of the main roof zone, and the main roof rock beam will be broken. Part of the force on the lower formation when sinking is released before being transferred to the stent. The thicker the composite roof plate, the more fragile the overall structure. The more energy is released from the main roof zone, the smaller the change in the support strength of the support. Therefore, the pressure of the composite roof working face is moderate, and the strength varies with the thickness and lithology of the composite roof.

(4) The front extension beam of the bracket can support the roof of the coal seam in time. When the roof of the coal seam is broken, the roof beam needs the backing plate to assist the roof to prevent accidents. The bracket retaining plate can prevent the meteorite generated during the coal mining
process from entering the working surface to a certain extent, but the support capacity of the support is
general, and the phenomenon of the coal wall ganging occurs sometimes. Therefore, it is necessary to
hit the temporary pillar in time to control after the coal is dropped.

![Combined sliding support pressure detection diagram](image)

**Figure 3.** Combined sliding support pressure detection diagram.

### 4.3. Working face effect
After more than one year of production practice verification, the combined sliding support is not as
safe and efficient as the fully mechanized hydraulic support, but compared with the traditional single
column support, the roof area and support strength are increased, the mechanization is improved, the
workers labor intensity is reduced, the monthly output of panel increased by an average of 5,000tons,
the highest daily output reached 820tons, the amount of emulsion used decreased by 221kg per month
and the overall economic benefits were obvious. The distance between the two pillars before and after
the support, the supporting direction and the initial supporting force, the connection between the group
and the group, the angle between the support retaining plate and the top beam and the strength of the
fixing pin have a great influence on the overall stability of the support, so reasonable settings should
be given during the production process. Therefore, reasonable settings should be given during the
production process.

### 5. Conclusion
(1) Although the combined sliding support has its own superiority, but it still belongs to the
improvement of the single bracket, the safety and stability can not be compared with the fully
mechanized hydraulic support, and there are also disadvantages such as the bracket connector being
easily damaged.

(2) The data analysis shows that the displacement of the roof and coal rib under the condition of
500KN, 800KN and 1200KN is considered. When the working resistance of the support is 750KN, the
surrounding rock control effect of the working face is better. The ZH1600/15/26B type support works.
Resistance can adopt production requirements.

(3) Production practice shows that the distance between the pillars and the direction of support are
selected, and the initial support force of the bracket is increased as much as possible to improve the
stability of the support. Not only can it support the direct roof, but it can also act on the basic top rock
layer. Under the condition that the bottom plate is soft, in order to achieve sufficient initial support
force of the bracket, the support bolts of the bracket pillars and the initial support force of the columns
of the proofreading brackets are substantially the same, and the roof top control effect is improved.
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