Research on Hydraulic Support Selection of Unmanned Fully - mechanized Coal Mining Face

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Abstract: The article introduced the knowledge about how to select the hydraulic support type. Aiming at the characteristics of thin coal seam in Huang Ling No.1 Coal Mine, by the use of empirical estimation method and numerical modeling method, the hydraulic support with large mining height was studied and selected. The article introduced its main technological parameters and characteristics. At the same time, the article proved that intelligent production pattern was an effective measure for unmanned mining on fully mechanized coal mining face, which had applied value popularizing on the mining face with thin and good condition of thin geology.

1Research background

The automation control technology of unmanned fully mechanized mining face in coal mine and its application are the important measures of realizing coal mining safely and efficiently. Thin coal seam unmanned mining is still the technological problem, especially extremely thin coal seam.

In America, Germany, and Australia, technology of unmanned fully mechanized mining face is more advanced [1]. Australia has more than 60% of the use of LASC long-wall automation system on fully mechanized mining face; The United States recently developed a set of thin coal seam long-wall equipment, and they are proposing to realize unmanned mining in Norway coal mine[2][3].

In China, there are also many units carried out the research of unmanned and less humanized fully mechanized mining face. At present, there are several territory has realized unmanned and less humanized mining on fully mechanized mining face [4].

Face selection and matching of fully mechanized equipment is related to the stability and reliability of fully mechanized equipment, and the intelligent degree of the fully mechanized coal face at the same time. Face "compressors" selection includes the selection of hydraulic support, coal winning machine and scraper conveyor. Among them, the selection of hydraulic support is the core.

1.1Research at home and abroad

Electro-hydraulic control system of Hydraulic support is increased as additional products after support production, which does not really blend into the hydraulic support structure [5]. In order to ensure the normal use of hydraulic support electro-hydraulic control system, intelligent frequency conversion intensively liquid system is developed, a set of liquid-providing system was established, which providing highly efficient hydraulic cleaner sources of power for mining face [6][7].

As the selection of hydraulic support of unmanned fully mechanized mining face, Australia designed the mining face straightening system based on mining face automatic control algorithm included in LASC system, through the analysis of the space position of shearer recorded by rudder navigator, the current mining face straightness was determined, the quantity of each course of hydraulic support was calculated, which could give perform message to hydraulic support electric control system, and dynamically adjust straightness of mining face[8].

Since the 1990's, electro-hydraulic control system's research and development had begun to carry out domestically, and applied well.

1.2 Introduction of Huang-ling mining area

The main basic mining bed thickness of Shaanxi coal group of Huang-ling coal mining company No.1 coal mine is 2m or more. But the mining face of thin coal seam on fully mechanized coal face is low and narrow, there are also many operators, machine operation is difficult, production environment is bad, which could due to any production safety accident and occupational disease.

The target of intelligent unmanned comprehensive mechanized mining of Huang-ling was the process of unmanned mining face production, the main technical difficulty is the need to use remote control to control the production process, and this is a set of comprehensive application of many technologies such as automation, detection, video, communication, control, and the computer. Among them, the hydraulic support full mining face with machine automation and remote manual intervention is one of the main key technologies needs to be solved.

2 Selecting process of hydraulic support

2.1 Selection principle

The selection of frame type of support should be adapted to geological conditions of mining face, the frame structure should be adapted to coal seam occurrence condition, support section should be adapted to ventilation requirements, and hydraulic support should match the coal mining machine, conveyor and other equipment. Through decades of mining mechanization development at home and abroad, the type of fall-seam mining hydraulic support frame had two main types: cover type (two pillars) hydraulic support and the support cover type (four pillars) hydraulic support.

At present, the international development trend of hydraulic support frame type is two pillars cover timbering with high mining resistance, high availability, long-wall face in Germany and the United States has all adopt two pillars cover timbering, Australia, South Africa and some other traditional countries mainly using the support cover timbering have had switched to two pillars cover timbering. Some of China's new large-scale modernized high production and efficiency mine had also adopt two pillars cover timbering.

Based on the analysis above and consideration of the actual geological conditions of the Huang-ling coal mine No.1 coal seam, choosing two pillars cover timbering is reasonable.

2.2 Determination of bracket height

The main basis for the confirmation of the mining face mining height was coal thickness (including coal seam thickness with dirt band), at the same time, equipment capacity and mining pressure state should be also considered.

After the statistical analysis of the data of ten panel and five panel of Huang-ling No.1 coal seam, the appropriate mining height is 1.4 ~ 2.3m, bracket height is 1.15 ~ 2.4m.

2.3 Support under frame sinking prevention design

To prevent under frame sinking, the bottom was taken up in the process of stent design, as shown in Fig 1.

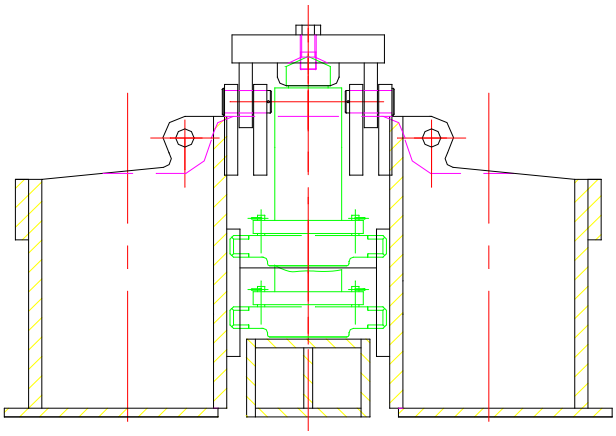

Fig.1 sketch map of lifting bottom organization

Lifting bottom organization could lift the front bracket to support moving smoothly when support moved forward, which could not only prevent under frame sinking but also solve the problem that support moved difficultly while bottom plate is not flat.

2.4 Determinations of bracket support strength and mining resistance

The determination of hydraulic support strength is one of the research emphasis of strata control on fully mechanized mining face, the aim is to make the mining strata control be under the premise of the optimal technical and economic effect, under the condition of the reasonable scaffold structure, ensure high reliability bracket operation and high production and efficiency of mining face.

According to the actual geological condition of coal seam, the research used the experience estimation method, numerical simulation analysis method based on the relationship of supports and surrounding rock, to the reasonable mining resistance of the stent was determined, which ensured safe and efficient mining.

(1). Experience estimation method

According to the interaction relationship of support and surrounding rock, the station of support stress of mining face could be divided into two parts: one is directly on the top of the load Q_1; the second is the old top acting on the support through direct load Q_2.

a). Direct roof load Q_1

$$Q_1 = \sum h \bullet L_1 \bullet \gamma \quad (\text{kN/m}) \tag{1}$$

In the formula: $\sum h$ --Thickness of immediate roof; L_1 --Hanging arch length; γ --Volume forces.

The hanging arch length could be regarded as roof width of the support L, then

$$Q_1 = \sum h \bullet L \bullet \gamma \tag{2}$$

The load is:

$$q_1 = \sum h \bullet \gamma \quad (\text{kPa}) \tag{3}$$

b). The main roof load Q_2

Multiples of immediate roof load was used to estimate the load on the top of the old roof, it's still possible in the general case. For example, in the determination of the majority of mine, it would be subject to general mining face, load formed by periodic weighting would not be bigger more than twice the normal load. Therefore, the following relationship could be come:

$$p = q_1 + q_2 = n \bullet \sum h \bullet \gamma \tag{4}$$

In the formula:

p - support strength considering the immediate roof and main roof weighting; N - the ratio of old roof pressure and the intensity of normal pressure, known as the load coefficient, take the value of 2.

Take $\sum h = \frac{M}{K-1}$ (M is mining height, K is bulking coefficient), then：

$$p = 2 \times \frac{M}{K-1} \times \gamma \tag{5}$$

K generally is been took 1.25 ~ 1.5 multiple of the hulking coefficient:

$$p = 2 \times (2 \sim 4) \times M \times \gamma = (4 \sim 8) M \times \gamma \tag{6}$$

According to the practical geological conditions of mines, the largest mining height of mining face is 2.3m; the average coefficient of rock layer of top roof is2600kg/m³, $\gamma = \rho g =$ 26000kg/s2m2, additional coefficient is 8, the reasonable supporting strength of support is:

$$p = 8 \times 2.3 \times 26000 = 0.48 MPa \tag{7}$$

The bracket support strength should not be determined by this method less than 0.48 MPa.

(2). The numerical simulation analysis method based on the mutual relationship between supports and surrounding rock

Based on the theory of “P-ΔL” curve, respectively the stent supporting strength of 0 MPa, 0.3 MPa, 0.5 MPa, 0.6 MPa, 0.7 MPa, 0.8 MPa, 0.9 MPa was simulated, bracket support strength and the 5 m of the back of face at the roof subsidence curve is shown in Fig. 2.

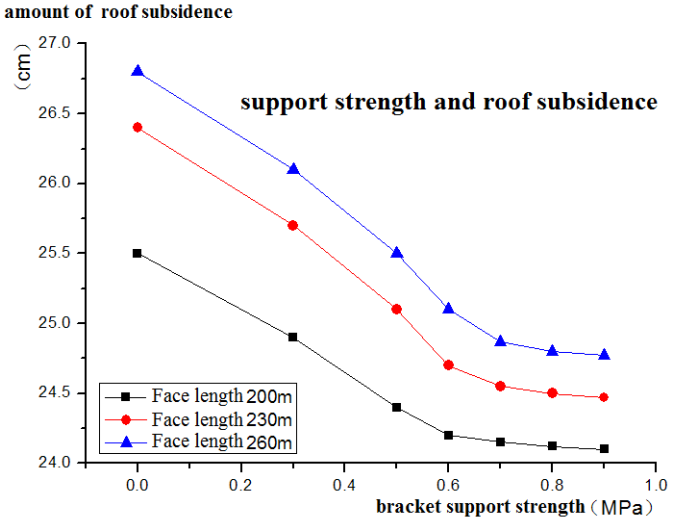

Fig. 2 bracket support strength and roof subsidence curve

The figure shows that the 5 m of the back of face at the roof subsidence increases with the mining face length increasing, mining face length was 200 m, the bracket support strength was 0.6 MPa, the degree of the roof subsidence increasing along with the increase of bracket support strength significantly decreased, so the suitable bracket support strength is greater than 0.6 MPa.

When mining face length was 260m, the bracket support strength is greater than 0.7MPa, the degree of the roof subsidence increasing along with the increase of bracket support strength significantly decreased, so the suitable bracket support strength is greater than 0.7MPa.

The reasonable supporting strength of two calculation methods of support were comprehensively analyzed, reasonable supporting intensity of relatively thin coal seam of the Huang-ling No.1 coal mining should be greater than 0.7 MPa.

(3). The determination of support mining resistance

The rated mining resistance F can be calculated by the formula below:

$$F \geq \frac{P \times B_c \times L}{\eta} \tag{8}$$

In the formula:

P—the intensity of fully mechanized mining face rated support strength, is 0.7 MPa; L - support center distance, is 1.5 m; B_c - face width, take 5.5 m; η - support efficiency, is 0.9.

Take above parameters to the formula to calculate, then

$$F \geq \frac{0.7 \times 5.5 \times 1.5}{0.9} = 6417kN \tag{9}$$

On account of series of support pillar diameter, and big support pillar slope of thin coal seam face, effective supporting force is small, ultimately determining support mining resistance rating is 6800 KN.

3 Main technical parameters of support

3.1 Hydraulic support's final selection

According to the calculation results above, main technical parameters of support is as follows:

Table 1. Main technical parameters

No.	name	parameter	unit	remark
1	type	hydraulic support (two pillars)		
2	height	1150～2400	[mm]	
3	width	1430～1600	[mm]	
4	center distance	1500	[mm]	
5	setting load	4756	[kN]	P=31.5MPa
6	mining force	6800	[kN]	P=42.3MPa
7	support intensity	0.78～0.91	[Mpa]	f=0.2
8	beta ratio to front end of floor	2.8～3.2	[Mpa]	f=0.2
9	suitable mining face slop	≤15°		
10	unit advance	800	[mm]	

(1). The structure characteristics of the hydraulic support are as follows:

1) Stent type is two pillars types with four connecting rod hydraulic support.

2) Top beam structures used integrated roof timber; the front end of the top beam support is big.

3) Support top beam and cover beam are all designed unilateral side guard plate, which was used to guide for adjusting and moving.

4) support stable institutions are four bar linkage, front and end connecting rod is the connecting rod, the structure has good stability, tensional performance of four bar linkage is high.

5) Bottom of support uses bottom fraction integral rigid base, with good rigidity, float coal and broken bottles moved to equipment could be moved to mined-out area with support, no manually.

6) Bridge of bottom designs lifting organization, which could lift front end, ensure smoothly shift.

7) Push and move structure uses the type of inversion long push rod, whose pulling strength is big, pushing strength is small, and the whole rigid push rod has simple structure and good reliability.

8) Single balance jack was set between the cap and cover beam, which is used to adjust the attitude of the top beam and the resultant force point position on the top beam.

(2). The main hydraulic system of hydraulic support is as follows:

1) Nominal diameter of cross heading main feed pipe DN50S; nominal diameter of the liquid return pipe DN63; main water pipe for spry DN40.

2) Nominal diameter DN32 of pipe between spray system frames

3) Nominal diameter DN40S of high pressure pipe between frames, nominal diameter of the liquid return pipe DN50.

4) There is high pressure filter before feed pipe entering the work station, filtration precision is not greater than 25μm, and the traffic is not less than 1000 L/min.

5) Main pipeline configuration of each holder is equipped with high pressure cut-off valve; main liquid return pipeline is equipped with liquid return breakers.

6) Each holder is equipped with reverse-washing filter; filtration precision is not more than 25μm.

7) Each pillar is installed with large flow relief valve with flow of no less than 500 L/min.

8) There is a pressure gauges installed behind post inferior vena of each hydraulic support pillar to monitor the mining pressure of the post.

9) Stent uses electro-hydraulic control system; electromagnetic directional valve flow rate is not less than 400 L/min.

(3). Main material of hydraulic support is as follows:

1) Structure frame

The structure frame such as bracket push rod, foundation, top beam, cover beam and connecting rod, and soon on, use high strength steel plate, other parts use common plate, different proportion distribution of sheet support structural performance is: Q690 accounts for 70%, Q550 and Q460 accounts for 30%;

2) The hydraulic cylinder and the piston rod

The steel pipe of hydraulic cylinder adopts 27SiMn steel tubes, common optimization specifications of support are used for the pipe specifications;

This support jack piston rod selects 27SiMn bar.

3) The pin shaft, guide bar

More important pin shaft adopts 30CrMnTi or 35CrMnSiA bars, the weight accounts for about 80%; the rest all use 40Cr bar, the weight accounts for about 20%;

Pin shaft and guide bar are galvanized and passivity.

4 Conclusions

Domestic equipments and technology were adopted at intelligent coal mine mining face of No.1 coal mine. By preliminary estimation, the price of a set of domestic coal fully mechanized equipments intelligent system is about 2/3 of foreign products.

Compared with the traditional fully mechanized mining, the persons of mining area decreased from 9 workers joint (3 machine drivers, 5 timber-men, a conveyor driver) to 1 inspector, advance single support mode of two consecutive monomer changes to automatic fore-poling supporting method, the operators decreased from 8 workers per shift to 4 workers remote control (intake and return air station each 2 workers, one operator, one monitor). Worker's number of single class decreased from 19 (including a belt driver and an electrician) to 7.

Intelligent unmanned mining moves workers from the mining face with high risk to safety environment—monitoring center of cross-heading even ground control command center, which fundamentally improved the operation safety coefficient. The successful application of the project is a reference for other coal mines' fully mechanized coal mining of thin seams.

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