Study on electro-hydraulic control system of advanced support in large section roadway

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Abstract. Taking the large cross-section return air roadway of 4201 working face in No.2 panel of Liuzhuang Coal Mine as engineering background, the engineering geological conditions and supporting conditions of roadway were analyzed, and the 3×ZQL2×5200/23/45WD split advanced support was used to support the roadway in the advance support area. On this basis, the design schemes of support pressure monitoring system, automatic deviation adjustment system, environmental monitoring system, remote control system and software control system were analyzed, the subsystems with different functions constitute the electro-hydraulic control system of advanced support. The advanced support has good application effect and can meet the requirements of advanced support and automation control of large cross-section roadway.

1. Introduction
With the continuous development of science and technology, China's fully mechanized mining technology and equipment has made considerable progress: the complete set of equipment consisting of high-power shearer, scraper, strong hydraulic support and long-distance transfer equipment provides guarantee for high-yield and high-efficiency of fully mechanized mining face, which has great significance for safe and efficient mining of coal resources [1-4]. At present, the main mining areas have basically realized comprehensive mechanization, which not only improves the production efficiency of the working face, greatly reduces the working intensity of underground workers, but also ensures the safety of the working face. However, as far as the advance support is concerned, there are still many mines that can not effectively solve this problem. On the one hand, the traditional single hydraulic prop support is used, on the other hand, the advance support control system of roadway is backward. Under this support mode, there will be some unfavorable factors, such as low support strength, slow support speed, strong labor intensity and low safety of workers. For high-yield and high-efficiency fully mechanized mining face, the pillar can't meet the support requirements of its rapid advance [5-6]. In order to solve the above problems, this paper takes the 6201 large high mining face of Wangzhuang Coal Mine in China as the engineering background, according to the specific geological conditions, the advance support group of the return channel was designed, and the electro-hydraulic control system of the advance support group was analyzed, which realizes the automation of the advance support along the channel and improves the safety and reliability. On the basis of this, the labor intensity of workers has been greatly reduced, which has good technical and economic benefits.
2. Basic situation of working face and roadway

4201 face is the first working face in the second panel area of Liuzhuang Coal Mine, located in the east of the second panel area, the eastern part of the working face is the boundary of the mining area, the western part and the northern part are solid carbon areas, and the southern part is the main transportation lane of the mining area. The tendency and strike length of the working face are 250 m and 2586 m, respectively; the thickness of coal seam is 4.86~6.53 m, and the average thickness is 6.02 m. The roof and floor of coal seam are as shown in Table 1.

| Name          | Rock            | Average thickness | Characteristic                                      |
|---------------|-----------------|-------------------|----------------------------------------------------|
| mainRoof      | Sandstone       | 30.5              | Composition is mainly quartz, feldspar, containing a small amount of mica chips and dark minerals, the particles are round, medium separation |
|               |                 | 11.63~49.24       |                                                    |
| immediate roof| sandy mudstone  | 2.07              | Gray-black, with foliage fossils of plants and horizontally to gently wavy bedding |
| Immediate     | mudstone        | 1.3~5.06          | Dark grey with horizontal bedding and pyrite-bearing film |
| bottom        | mudstone        | 1.98              |                                                   |
|               |                 | 0.94~3.2          |                                                    |
| main bottom   | sandy mudstone  | 9.51              | Gray-green, horizontally bedded, thin mudstone-bearing beds in the middle |
|               |                 | 2.8~19.8          |                                                    |

6201 return tunnel is a rectangular section with a net width of 5.2 m, a net height of 3.8 m and a net section of 19.76 m². The roof is supported by threaded steel resin bolts with the specifications of φ18×3100 mm, and the spacing and row spacing are 900 mm, respectively. The anchor cable is 17.8mm pre-stressed steel strand with a length of 6.5m and a spacing of 1.8m. The two sides are supported by bolts and steel mesh. The specifications of bolts are φ16×1600 mm, and the spacing and row spacing are 1000 mm and 900 mm, respectively. As is shown in Figure 1:

![Figure 1. 3×ZQL2×5200/23/45WD split advanced support.](image)

3. Advance support scheme

The advance section of the roadway is supported by 3×ZQL2×5200/23/45WD split support group, the support adopts a new type of narrow four-bar mechanism, and takes into account the supporting characteristics of roof bolts and anchor cables, which enhances the adaptability of the roof and reduces the damage to the roof. The support group is symmetrically arranged on both sides of the roadway, and the support length is 28m. The main technical parameters are as follows.

- Frame type: split
- Support range: 28m
- Support height: 2.1m~4.2m
- Initial resistance: 21504kN (P=42.5MPa)
- Working resistance: 30000kN (P=42.5MPa)
- Support strength: more than 0.19 MPa
Support width: 3.5m~6.0m
Control mode: electro-hydraulic control

4. Electro-hydraulic control system
The rapid development of electro-hydraulic control system greatly improves the convenience, reliability, safety and automation of hydraulic support control, and makes great contributions to high production and efficiency of working face [7-8]. In this paper, the electro-hydraulic control system of advance support is designed to meet the control requirements of surrounding rock of large cross-section trench in large mining height working face.

The advanced support group consisted of three groups and six units, and each support unit is equipped with a controller, using the same power supply and automatic backwash filter, which can realize the control of relevant hydraulic valve bodies, such as front and rear columns, push jacks, front and rear short columns, side roll beams, Jack beams and base anti-overturning jacks. The schematic diagram of electro-hydraulic control system is shown in Figure 2.

![Figure 2. Schematic diagram of electro-hydraulic control system.](image2.png)

4.1. Pressure monitoring design
During the actual stretching and falling process, the roof beam and roof repeatedly contact with each other, which has a certain impact on the roof, therefore, the working resistance of the support should be controlled within a certain range: when the working resistance of the advanced support is too low, the deformation of the roadway may increase; when the working resistance is too high, the support will cause damage to the roof in the process of repeated support. The pressure range can be adjusted according to the damage degree of surrounding rock at different locations. The advanced support controller is shown in Figure 3.

![Figure 3. Advanced support controller.](image3.png)

4.2. Automatic deviation adjustment system
In large cross-section roadway, the advanced support has a larger support height. In actual production process, when the roadway floor is uneven or the roof is relatively broken, it is easy to cause the
instability or displacement of the advanced support. Therefore, the automatic deflection adjustment system of support is introduced. In the system, the tilt sensor of the column and the tilt sensor of the pushing cylinder cooperate with the support controller. The inclination sensor will monitor the data in real time and send it to the controller, which can analyze and process the data. When the inclination angle of the column and the pushing cylinder exceeds a certain range, the controller can adjust the running attitude of the support by adjusting the anti-damping cylinder and pushing cylinder.

4.3. Environmental monitoring system

In order to ensure the safety of roadway working space, an environmental monitoring system is set up in the electro-hydraulic control system. The environmental sensors in the system can real-time monitoring the specific parameters such as temperature, gas concentration, wind speed and air volume along the roadway. When a certain parameter reaches the set value, the controller will issue relevant instructions to control the sound-light alarm to send out a report, which can remind the field operators to take corresponding measures to ensure the safety of production along the trough.

4.4. Remote control system

In order to facilitate operation, a remote control system is set up in the electro-hydraulic control system, the transmitter is a multi-functional remote controller, and the receiver is installed in the controller of the roadside support device. Operators can send control signals to the advanced support through multi-function remote controller within 100 meters of support area, and transmit them to receiver in the form of infrared wireless signal. After the controller receives, the signal is analyzed and converted by the multi-function reversing valve, and then the corresponding valve body is issued instructions to perform the relevant actions. As is shown in Figure 4:

![Figure 4. Diagram of remote control system.](image-url)

4.5. Software of electro-hydraulic control system

The electro-hydraulic control system adopts the mode of combining local control with remote control. In local control, the new controller adopts Ethernet communication protocol, and the communication rate reaches 100Mb/s, it can realize real-time monitoring data transmission along the slot, neighborhood control, group control, online detection, voice and video transmission and other functions. In remote control, the control system can realize linkage control with the "three machines" control system and transportation system of the working face. Each control system adopts industrial Ethernet protocol, which can transmit real-time monitoring data from underground to the ground centralized control center. At the same time, the command data from the ground control center can be transmitted to the working face for ground control. The system realizes the fast transmission and remote real-time control of data up and down wells.
5. Application effect
3×ZQL2×5200/23/45WD split advance support group has been used in the air return channel of 6201 high mining face in Wangzhuang Coal Mine, at present, the working face has been pushed forward more than 1000 meters. During the use period, the support electro-hydraulic control system has not broken down, which shows that the system is safe and reliable in design and can meet the advanced support of large cross-section roadway in high mining face.

6. Conclusions
(1) The engineering geological conditions of 6201 large cross-section return air roadway are analyzed. It is determined that 3×ZQL2×5200/23/45WD type advanced support group is adopted for advance support of roadway.
(2) The composition and principle of the electro-hydraulic control system of the 3×ZQL2×5200/23/45WD split advanced support group are introduced, and the design scheme and software design scheme of the pressure monitoring, operation attitude control, environmental monitoring system of the advance bracket electronic control system are analyzed. The system is safe and reliable, and can meet the requirement of advanced support for large cross-section return air roadway in large mining height face, and realize automatic control synchronously with fully mechanized mining face.

Acknowledgements
This work was supported by the Science and Technology Innovation Venture Capital Special Project of Tiandi Co., Ltd (2018-TD-QN-040, 2018-TD-QN035).

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