Optimization Design of Drill Console for ZDY650 Type All Hydraulic Drilling Rig

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Abstract: In order to further improve customer satisfaction and market competitiveness of products, after a lot of market research and scheme discussion, Xi'an Research Institute of China Coal Technology and Engineering Group Corp set up a special project team to carry out the ZDY650 drill console optimization and promotion. The internal structure of the console has been rationally laid out, and the integrated adapter plate assembly has been added. Wire drawing panel and front, rear, left and right shields on the console were designed to enhance safety protection and improve appearance quality. Key hydraulic components such as anti-seismic pressure gauge, multi-way reversing valve, hydraulic pump, and hydraulic motor and manual reversing valve group were optimized, and the operation performance of the console was dramatically improved.

1. Introduction
Xi'an Research Institute of China Coal Technology and Engineering Group Corp formerly known as the "Beijing Institute of Coalfield Geology" was established in May 1956 in Beijing, then moved to Xi’an in 1965 and now belongs to China Coal Industry Group Co., Ltd. It is a large scientific and technological enterprise under central management. After more than 60 years of development, it has become the only national key high-tech enterprise that specializes in coal geology and exploration in China's coal system and has outstanding advantages in the fields of geological guarantee technology, equipment and engineering for safe and efficient mining of coal mines. It is currently the largest and most market-share scientific and technological innovation enterprise in China that produces fully hydraulic tunnel drilling machines. Its main products ZDY series fully hydraulic drilling machines and instruments are sold at home and abroad. However, with the development of intelligent manufacturing industry 4.0 at home and abroad[1], the level of drilling equipment manufacturing industry has developed rapidly. Coal mining requires not only complete functions of equipment, but also reliable, safe, beautiful and ergonomic interactive design[2][3].

Through market research and feedback from long-term cooperative customers in coal mines, Xi’an Research Institute has set up a project team to upgrade and optimize the ZDY650 split drill console, a product developed earlier[4][7]. After the optimization design, the performance of the console has been further improved, the safety protection performance has been enhanced, and the integrated adapter plate assembly has been added. Wire drawing panel and front, rear, left and right shields on the console are designed to enhance safety protection and improve appearance quality. Key hydraulic components such as anti-seismic pressure gauge, multi-way reversing valve, hydraulic pump, hydraulic motor and manual reversing valve group were optimized, and the operation performance of the console was further improved.
2. Internal structure integration

2.1. Internal structure integration
The input and output hydraulic oil pipes of the console were designed in an integrated way, which was integrated on the adapter plate to make the connecting pipes more tidy and stable. The adapter plate and the frame were movably connected by bolts for easy maintenance. Figure 1 was a schematic diagram of ZDY650 frame and adapter plate.

In order not to affect the pipeline connection, the internal multi-way valve, manual reversing valve, pressure reducing valve and other positions were reasonably arranged and fixed to make the internal structure more tidy and the valve parts more stable [8]. Figure 2 was the layout diagram of the hydraulic valve of ZDY650 console.

2.2. Standardization of Parts
Combing the joints, nozzles and oil pipes required for the assembly of the console, classifying and standardizing the components with very similar structures and sizes, and designing hundreds of components into dozens through classification and standardization. In the process of classification and standardization design, we tried our best to avoid special-shaped fixed products and selected standardized common products [9]-[10]. The standards of the components were convenient for material procurement, storage and distribution of stored materials, as well as assembly in the production process, so as to improve the production efficiency. At the same time, it is also convenient for the post-sale service and maintenance of the console.

3. Optimization of console performance
In the optimization process of the console, a large brand of high-quality anti-vibration pressure gauge was selected to replace the common pressure gauge. The common pressure gauge had the ability of poor reliability, and often has the defects of non-return of the pointer to zero, no indication on the pointer of the pressure gauge. The preferred new anti-vibration pressure had the good performances of beautiful in appearance and reliable in performance. At the same time, according to customer's feedback, the first-class domestic brand manual reversing valve group was selected to replace the original manual reversing valve [11], thus the reliability and stability of the console were improved.

The explosion-proof rubber hose is preferred. Most of the hydraulic pipelines in the original console were connected by steel pipe butt welding, which had poor interchangeability between pipe fittings of the same type, was inconvenient to assemble and maintain, and often causes oil leakage from weld sand holes. In addition, the appearance quality of welded seamless steel pipes was poor due to uneven welding spots. In the optimization process, high-quality explosion-proof hydraulic hose was adopted to replace most seamless steel tubes, reducing the number of steel tube connections and improving interchangeability and reliability.
High voltage test line was preferred. The copper pipe used in the original console had many leakage points and poor reliability, and the defects such as blockage in the pipe often occur in the welding process. In addition, the copper pipe had poor flexibility in the installation process and had limit room for adjustment when encountering pipe interference. Therefore, high voltage test wire was preferred to replace copper pipe, and high voltage test wire had higher appearance quality than welded copper pipe, thus improving appearance quality and product performance.

4. Appearance design of console
The pressure dial and the upper panel were integrated, and stainless steel wire drawing panel is bent and stamped. At the same time, the multi-way valve and pressure gauge labels were etched directly onto the panel, as shown in Figure.3.

Fig.3 Dial and panel design
Fig.4 Shield design

The front, rear, left and right shields of the console were designed to increase safety protection and beautify the appearance of the console [12]. In particular, the left and right shields were designed with louvers, which was beneficial to heat dissipation and beautify the appearance, as shown in Figure.4.

In order to avoid the generation of gaps between the shields, the front, left and right guard plates were now bent at their edges, the upper wire drawing plate edges were rounded to overlap with the bent edges of the left and right guard plates, thus avoiding the generation of gaps when the shields overlap, as shown in Figure.5.

Fig.5 Overlapping design of shield

5. Optimization results

5.1. The assembly efficiency is improved
By optimization design of ZDY650 console, the assembly time was greatly shortened, the assembly efficiency was improved, the production cost was saved, and the production capacity will be improved. In order to measure the improved value of assembly efficiency after optimization, the assembly time of ZDY650 console before and after optimization was counted by the same group of workers, and the
average time required for main processes of a single console is further calculated. The calculation results show that the assembly time of the single rig console before optimization was 5.84 hours, and the assembly time of the single rig console after optimization was 3.23 hours.

Shortening rate = (5.84 - 3.23)/5.84*100% = 52.87%.

From the above formula, it can be concluded that the assembly time for optimizing a single console was greatly shortened, the production efficiency was greatly improved, and good economic benefits were created.

5.2. Improvement of appearance quality

![Comparison of appearance before and after optimization](image)

Through the optimization design of the upper panel, front, rear, left and right shields of the console, the appearance quality of the console, the safety protection, and the customer satisfaction were improved. The appearance comparison before and after optimization was shown in Figure.6.

5.3. Commercial test

In order to test the pressure resistance of oil pipes, seals, joints and hydraulic components of the optimized console, pressure resistance tests were carried out on several optimized ZDY650 rig console prototypes according to the standard of MT/T776-2004 factory inspection specification for coal mine machinery hydraulic system assemblies, as shown in Figure.7. Adjust the system pressure of ZDY650 console to 24 MP, and keep the pressure for 8 minutes, there was no explosion or oil leakage. It was fully proved that the optimized control console will have good pressure resistance and sealing performance.

![Pressure resistance test](image)

The National Testing and Inspection Center has made detailed records and statistics on 20 ZDY650 rigs. The testing report shows that the performance parameters of ZDY650 rigs after the optimized design of the console can fully meet the requirements of the "MT/T776-2004 Factory Inspection Code for Coal Mine Machinery Hydraulic System Assemblies", which was improved over the original factory parameters.
6. Promotion and application
The ZDY650 drilling rig console developed by this project has participated in large coal mine equipment fairs in Taiyuan, Guizhou and Beijing, and has produced more than 200 units, which have been sold to large, medium and small coal mine enterprises all over the country and received unanimous favorable comments from customers. The State Rescue Center of the State Security Administration ordered 28 optimized ZDY650 rigs. The following figure.8 shows the ZDY650 rigs produced for the State Rescue Center, which have been approved by the leadership of the State Security Administration.

Fig.8 Optimized ZDY650 rig console

7. Conclusions
Based on the research and implementation of ZDY650 drill console currently produced by Xi’an Research Institute of China Coal Science and Technology Group, the project team has reached the following conclusions:

(1) The internal structure layout of ZDY650 console has been optimized to make its internal structure more orderly, tidy and stable, which is convenient for after-sales service and improves the stability of the product.

(2) The drawing panel meter on the rig console replaced the original steel panel design, and left, right, front and rear protective covers were designed. The left and right protective covers were designed with louvers. The safety protection design was increased without affecting ventilation and heat dissipation, and the appearance quality of the console was greatly improved.

(3) Through the optimization and standardized design of some hydraulic components of the current production console, its service performance has been improved, interchangeability has been strengthened, reliability has been further improved, sealing leakage points have been significantly reduced, product quality has been improved, and customer satisfaction has been greatly improved.

(4) After optimized design, the assembly efficiency of ZDY650 rig console has been greatly improved, the assembly time of a single console has been shortened by more than 50%, the production efficiency has been improved, the production cost has been saved, and good economic benefits have been created.

Author's brief introduction: Liu Qingxiu (1982.06), male, from Yi Chang, Hubei province, associate researcher, doctor's degree, currently works in the drilling equipment manufacturing center of Xi’an research institute of China coal science and technology group, mainly engaged in the research and development of drilling equipment and rescue equipment, and has published more than 10 papers.

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