Research Status and Development Trend of Coal Mine Tunnel Drilling Rig in China

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Abstract: Aiming at the new progress and new trends of coal mine tunnel rigs in China, this paper introduces the development of conventional coal mine tunnel rigs, discusses the application of new technologies such as directional drilling and remote automatic control in the development of coal mine tunnel rigs, and points out the development trend of coal mine tunnel rigs in China. According to the development of domestic coal mine tunnel drilling rigs and related technologies, it is of great significance to construct intelligent drilling face and comprehensively improve the adaptability and reliability of mine tunnel drilling machine to ensure the safety and efficient production of coal mine.

1. Introduction
With the development of new technologies such as intelligent technology, remote control technology and computer technology, the safety of coal mine production in China has been gradually improved, and the mechanization of coal mine production has made great progress. However, this has not fundamentally changed the nature of coal mine production as a high-risk industry. Coal mine gas accident and the damage are still the main threat to the threat of coal mine safety production accident, therefore summarized specially used for mine gas extraction and drain the research status and development trend of coal mine tunnel drilling rig, develop more suitable for a new type of coal mine underground drill and domestic demand to ensure the high-efficient and high-yield of coal mine safety production in China has very important significance.

Materials and Methods

2. Research Status of Mine Conventional Tunnel Drilling Rig
Coal mine tunnel drill refers to the special equipment for all kinds of drilling construction in the underground coal mine. According to the structure, it is mainly divided into two categories: split tunnel drill and crawler tunnel drill, as shown in Figure 1.
2.1. Mining split tunnel drilling rig

The mine split tunnel drilling rig is mainly used in small and medium-sized coal mines and mines with small roadways. It consists of pumping stations, mainframes and consoles with independent structures. It is small in size. The three major components can be transported separately, which has low requirements on the roadway environment. The structure is shown in Figure 2.

The development of split tunnel drilling rigs for mines in my country has been relatively mature. The Xi’an Research Institute of China Coal Technology and Engineering Group is the first unit to develop split drilling rigs in China. It fully utilizes the characteristics of small size and large torque of split drilling rigs and breaks through the drilling rigs. The construction of gas drainage and water detection and release in narrow roadways represents the latest achievements of domestic split drilling rigs. Since the main components of the split drilling rig are independent of each other, the underground transfer of the drilling site mainly relies on the backward handling methods such as man pulling the hoist, which makes the workers labor intensive and prone to safety accidents. At the same time, it takes a long time to stabilize the drilling rig. Shortcomings such as slower speed have severely restricted the development and application of split drilling rigs.

2.2. Mining crawler tunnel drilling rig

Integrating components such as the pump station, console, and fuselage of the split drilling rig on the crawler body produces a crawler drilling rig. When this type of drilling rig is used underground, it can rely on the crawler to walk, which greatly increases the relocation speed and reduces the labor of workers. Strength, reduce the settling time, improve the overall efficiency of the drilling rig. Figure 3 shows the crawler tunnel drilling rig.
Crawler tunnel drilling rigs are mainly used in medium and large coal mines or roadways. They are characterized by relatively large volume, large torque, wide angle adjustment range, and low opening angle, especially for long-distance transitions. The effect is high and the degree of automation is high. Save labor transportation costs and stabilization time, and improve the overall overall efficiency of the drilling rig. Domestic crawler drilling rig manufacturers are represented by Xi’an Coal Research Institute and Chongqing Coal Research Institute. They have achieved very good results mainly in high-speed drilling rigs, full dip drilling rigs, cut hole drilling rigs and high-torque drilling rigs, which have solved the problem to a certain extent. The problem of low drilling hole rate in soft coal seams can effectively deal with all kinds of stuck drilling accidents. It is well applied in the construction of gas drainage holes and water exploration and drainage drilling [1-2]. Although the traditional crawler tunnel drilling rig has excellent performance and low cost, it has a short hole-forming distance and is unable to carry out long-distance directional drilling construction. In particular, the disadvantages are becoming more and more obvious when the coal mine needs to carry out the construction of cross-layer holes and the construction and relocation of drilling field.

3. Research Status of Mine Directional Tunnel Drilling Machine

The mine directional tunnel drilling rig is a drilling rig that combines directional drilling technology and measurement while drilling technology, with a central cable-type drill pipe, a screw motor and an explosion-proof computer for long-distance directional drilling. The directional drilling rig has the advantages of long-distance operation, safety and reliability, strong process adaptability, extraction of toxic and harmful gases such as gas, and high precision of water detection and release.

The directional drilling technology is a drilling method that can design the drilling trajectory according to the drilling process requirements and make the drilling tool follow the designed trajectory. Directional drilling can open a main hole and open multiple branches on the main hole. The number and location of holes and branch holes are completed according to the drilling process and actual needs [3]. Through the application of directional drilling technology in coal mines, gas drainage and water exploration and drainage can be designed according to coal mine geological data, combined with coal mining needs to design the drilling trajectory in advance, control the accuracy of water exploration and drainage and gas drainage, and improve the effective drilling of gas drainage. The length of the hole improves the efficiency of water detection and drainage and gas drainage. In addition, through the multi-branch hole drilling process, it is possible to achieve uniform coverage of the entire mining working layer with one opening, reduce the number of openings, improve the efficiency of coal mine drilling, and improve the effect of coal mine water disaster and gas control.

At present, the most widely used directional drilling technology in coal mines in our country is the compound drilling technology. This technology means that while the power head drives the drilling tool to rotate, high-pressure water reaches the bottom of the hole through the cable drill pipe and drives the bottom motor to work. Directional sliding drilling is used in the process of tilting and descending, and rotary drilling is used to maintain straightness. Through the application of directional drilling rigs and directional drilling technology, the process of opening a hole and opening a branch hole can be used in the underground coal mine, which greatly improves the efficiency of gas drainage. Figure 4 shows a schematic diagram of gas drainage using directional drilling.
The research work of directional drilling rigs for coal mines in China is mainly concentrated in the China University of Mining and Technology, Xi’an University of Science and Technology, Anhui University of Science and Technology, and China Coal Technology and Engineering Group Xi’an Research Institute and Chongqing Research Institute. Among them, Xi’an University of Science and Technology and Xi’an Institute of Coal Science have jointly developed a coal mine full hydraulic drilling rig training system based on virtual reality technology for coal mine drilling rig operation training [4]; the series of directional drilling rigs developed by Chongqing Research Institute of China Coal Technology and Engineering Group focus on dual-motor power heads, quick-change chucks, large-diameter grippers, interlocking rotation and braking functions, Key technologies such as auxiliary upper and lower drill pipe devices have been studied, and they have performed well in long and deep hole construction and handling of stuck drill accidents [5]; the series of directional drilling rigs developed by Xi’an Research Institute of China Coal Technology and Engineering Group are adapted to coal mine tunnels. Good progress has been made in terms of performance, ergonomics and high-power and high-torque. Among them, the high-torque directional drilling rig has created a world record of 3,353 meters of ultra-long gas drainage directional drilling in Shendong Baode Coal Mine. Excellent performance in construction applications [6]. At present, our country has basically approached the world's leading level in the field of directional drilling rigs for mining. Especially in recent years, it has performed outstandingly in the development of high-torque and high-power directional drilling rigs. Directional drilling rigs with greater torque and power are also under development. However, Domestic directional drilling rigs often need to improve the quality of hydraulic components, and the degree of automation and informatization is low. It is necessary to increase the research and development of intelligent drilling rigs.

4. Research Status of Mine Intelligent Tunnel Drilling Rig

According to the requirements of "Made in China 2025" and the country's "14th Five-Year Plan", coal mining must be mechanized and automated to reduce the number of people going down on duty and completely reduce the number of deaths in my country's coal mining. In order to reduce the number of personnel in the drilling face, relevant domestic scientific research units have done some research on the automatic loading and unloading of drill pipes and fully automatic control of the drilling rig to reduce the number of people going down on the drilling face and improve the drilling efficiency. Yin Lei of Southeast University has conducted research on remote intelligent monitoring of drilling rigs to enhance the awareness of coal mine workers to drill in accordance with the operation guidelines and improve the safety of drilling sites [7]; The remote control drilling rig developed by Chongqing Coal Research Institute and Xi’an Coal Research Institute can keep operators away from power equipment and orifices, and improve the safety of drilling operations [8-9]; Cheng Yingsong of Anhui University of Science and Technology, Yao Yafeng and Li Xiaopeng of Xi’an Research Institute of China Coal Technology and Engineering Group have all studied the automatic loading and unloading of drill pipes by drilling rigs. The drill rod device has reached practical requirements [10]. Yao Ke and Dong Hongbo of Xi’an Research Institute of China Coal Technology and Engineering Group conducted research on remote control of mining rigs and intelligent drilling rigs [11-12], developed scientific research prototypes for industrial tests, and achieved certain results.
The above-mentioned research has achieved some stage results in the field of drilling rig automation. However, due to the late start of the development of intelligent tunnel drilling rigs for coal mines in my country, there are no mature intelligent tunnel drilling rigs for coal mines in foreign countries. In the stage of automation transformation, the level of intelligence and practicality need to be further improved. Many key technologies such as automatic loading and unloading of drill pipe technology, remote control technology, automatic drilling construction technology, online monitoring technology, etc. still need to be resolved. In view of the complex and narrow tunnel environment in coal mines, it is difficult for tunnel drilling rigs to realize automatic program control. The research and development of intelligent tunnel drilling rigs in coal mines in my country still requires continuous efforts and continuous investment.

Results & Discussion

5. Development Trend of Coal Mine Tunnel Drilling Rig

Although my country's mine tunnel drilling rigs have made great achievements after years of development, in the face of the new demands of coal mine production, with the development of new technologies and new processes, the development of my country's mine tunnel drilling rigs still needs to continue in the following four aspects:

5.1. High power and high torque

In coal mine gas management, the demand for ultra-long gas drainage holes, one main multi-branch hole, large diameter gas drainage holes and roof high-level drilling has increased significantly. Drilling rigs must have greater rotating torque and power. At the same time, high-power, high-torque drilling rigs have irreplaceable outstanding advantages in handling all kinds of stuck and buried drill accidents. Energy efficiency solves various emergencies in underground drilling construction, so it is necessary to vigorously develop more power and torque New coal mine tunnel drilling rig.

5.2. Automatic loading and unloading of drill pipe technology

During the construction of the drilling rig, it is often necessary to suspend drilling and unload the drill pipe. Generally, at least two workers are required to unload the drill pipe. In order to meet the needs of the directional drilling process, it is often necessary to repeatedly load and unload the drill pipe, which not only leads to workers The work intensity is high, and unsafe conditions occur from time to time during the process of loading and unloading the drill pipe. Therefore, this problem can only be solved effectively by replacing the manual loading and unloading of the drill pipe with automated mechanical labor, and it is also relatively easy to achieve. Therefore, the focus on the research and development of fully automatic loading and unloading drill pipe drilling rigs is of great significance for reducing the number of workers on the drilling site, improving the efficiency of drilling rigs, reducing labor costs, and ensuring the safety of drilling construction.

5.3. Remote control technology based on virtual reality

Virtual reality is a technical means of virtual simulation. It restores the actual situation through remote control and real-time data transmission. The application of virtual reality technology to high-risk work such as underground coal mine drilling and construction allows workers to operate the drilling rig at a safe distance. Essentially Solve the problem of injury to personnel caused by drilling construction accidents.

The research and development of remote control drilling rigs using virtual reality technology is mainly for the construction of virtual drilling rig control platforms. Through the establishment and real-time display and control of three-dimensional models of drilling rigs and drilling sites, the actual situation of drilling rigs downhole can be simulated in all directions in real time, so that operators can Operate the rig to perform construction on the virtual rig control platform on the well. The key point of this technology is to accurately obtain various parameters of the drilling rig under various working
conditions, and conduct real-time data interaction and issue control instructions, so as to ensure that the drilling rig completes the drilling construction accurately and safely.

5.4. Remote fault diagnosis and early warning
With the application of large-scale directional drilling rigs and new intelligent drilling rigs in coal mines, drilling rigs are becoming more and more complex, and underground workers are limited by their knowledge level. The original drilling rig maintenance and inspection methods can no longer meet the needs of the new situation, so it is necessary to establish a remote fault detection and early warning system for drilling rigs. That is, when the drilling rig is working underground, the various performance parameters and safety parameters of the drilling rig and the video monitoring images of the underground drilling site are uploaded to the coal mine console and the drilling rig manufacturer. More professional engineers monitor the operating performance of the drilling rig, before the drilling rig fails. Notify the downhole for inspections, deal with potential failures that affect the safe and efficient production of the drilling rig in time, and improve the trouble-free working hours of the drilling rig.

6. Conclusions
With the development of artificial intelligence and computer technology, in line with the country’s requirements for less human and even unmanned coal mines, mine tunnel drilling rigs must integrate 5G, artificial intelligence, and virtual reality while developing new types of high-torque and high-power drilling rigs. A drilling robot system capable of automatic loading and unloading of drill pipe, automatic adjustment of drilling posture and intelligent drilling was developed, and an information-based data interaction platform between underground drilling sites and drilling RIGS was built, laying a foundation for the ultimate realization of unmanned coal mine.

References
[1] Meng R., Yao K., Zhang R. (2018) Design and application of ZDY2800LG high speed spiral drilling rig. Coal Technology, 1:234-236.
[2] Li H. X. (2018) Development and application of ZYWL-6000 type large diameter hole drilling machine. Coal Mine Machinery, 8:152-153.
[3] Dong C. (2015) Directional drilling technology and development tendency in underground mine. Coal Science and Technology, 5:106-110.
[4] Wang T. L., Qiao J., Peng T. (2018) Training system for coal mine full-hydraulic drilling rig based on virtual reality technology. Industry and Mine Automation, 44(04):100-104.
[5] Yan B. Y. (2020) Several key technologies about ZYWL-23000DS high-power directional drill rig. Coal Mine Machinery, 48(3):12-15.
[6] Li Q. X., Wang X., Xu C., and so on. (2020) Key technology of drilling with ultra-long-distance directional hole for gas drainage along coal seam. Coal Science and Technology, 48(12):168-174.
[7] Yin L. (2018) Design of Monitoring Device for Coal Mine Drilling Rig Based on DSP. southeast university, Jiangsu.
[8] Lv J. J., Xin D.Z. (2019) Design of ZYWL-4000SY Intelligent Remote Control Automatic Drilling Machine. Coal Mine Machinery, 40(3):4-6.
[9] Zhang G., Song H. T., Wang Y., and so on. (2020) Development and Application of Remote Controlled Low Hole Full Inclination Crawler Drilling Rig in Coal Mine. Coal Mine Machinery, 41(3):142-144.
[10] Cheng Y. S., Zhang L.X. (2018) Design and Analysis of Automatic Install and Pull Rods Mechanism of Drilling Rig. Coal Technology, 37(04):222-225.
[11] Dong H. B., Yao N. P., Ma B., and so on. (2020) Research on electronically controlled automation technology of underground drilling rig for coal mine. Coal Geology & Exploration, 48(3):219-224.
[12] Yao K. (2020) Intelligent drilling rig for coal mines and discussion on problems. Exploration Engineering (Rock & Soil Drilling and Tunneling), 47(10):48-52,71.