Application of Remote Control Technology in Gas Drainage Drilling Rig in Coal Mine

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Abstract. In view of the potential safety hazards such as gas-shot, gas-outburst and personal injury in the construction of gas drainage and drilling in coal mine, the technology and equipment of controlling drilling rig far away from the drilling field are studied to improve the automation level. This technology can realize the "one-key" mode to control the drilling machine to automatically up and down the drill pipe, automatically drill and back out, reduce the number of field operators, and play a positive role in ensuring the safety of gas extraction drilling personnel and reducing personnel and increasing efficiency.

1. Introduction

There are potential safety risks such as gas blowout and outburst in the construction of gas drainage holes in coal mine. The drilling construction with conventional drilling rigs requires manual loading and unloading drill pipes. Due to the heavy weight of drill pipes, the labor intensity of workers is very tired. There are many operators of conventional drilling rigs, and the risk of injury exists in rotation, propulsion and system failure of drilling rig. Remote control of underground gas drainage drilling construction can improve the automation level of drilling rigs, reduce the labor intensity of workers and improve the drilling efficiency; on-site unmanned operation can greatly ensure the safety of both operators and mine production; remote automatic control of drilling rigs on the ground can reduce the number of workers underground, realize the unmanned drilling site, and lay a solid technical foundation for the underground unmanned mining of coal mine. This technology can control the drilling machine to drill and withdraw automatically with one-key mode, and realize automatic moving, anchoring and positioning. As a result, the unmanned process of underground drilling is promoted, accidents such as coal and gas outburst are effectively eliminated and the safety of coal mine production is ensured.

2. Working Principle of Remote Control of Drilling Rig

2.1. Composition of the Remote Control Drilling Rig

The remote-controlled drilling rig is mainly composed of ground control station, main control station, power system, camera, attitude meter, manipulator, gripper, crawler, drill pipe box, electro-hydraulic control system, etc. as in Figure1. The functions of the main components are described below.
2.1.1. The manipulator

The manipulator is composed of an angle adjusting mechanism, an extension mechanism and a grabbing mechanism. The angle adjusting mechanism is composed of an upper supporting column, a lower supporting column and a hydraulic cylinder. The cylinder stretches out and draws back to make the upper supporting column rotate around the pin axis, so as to ensure that the manipulator and the frame are at the same angle. The telescoping mechanism is composed of a two-stage telescoping cylinder, a fixed sliding rail and a moving sliding rail, and the grabbing mechanism is installed on the moving sliding rail. The grabbing mechanism is driven by a hydraulic cylinder to the position of drill pipe in the box, and the slips are driven by another cylinder to open and clamp to grasp or feed the drill pipe \[^2\].

The manipulator has four executive actions, namely: angle adjustment, turning, stretching and clamping. By adjusting the inclination angle of the rotary reducer, the stepless adjustment of -90° ~ +90° can be realized in theory. The expansion joint driven by the expansion cylinder and the turnover joint driven by the hydraulic motor decompose the motion track of the drill pipe into L-shape, and the stroke of the cylinder depends on the length of the long side of the L-shape. In the specific design, the distance from the turnover center line to the center line of the top double gripper is taken as the stroke of the cylinder. In order to reduce the external dimension of manipulator, the expansion joint adopts the form of combination of internal and external expansion tubes. The gripper is a unilateral clamp mechanism driven by hydraulic cylinder, which performs the drill pipe clamping.
The positioning accuracy of the manipulator's three degrees of freedom of inclination, overturn and expansion directly determines whether the drill pipe can be transported in place. This has an important impact on the realization of the automatic loading and unloading drill pipes, and automatic drilling function of the remote-controlled drilling rig. In the industrial manipulator, visual positioning technology is often applied to determine and control the target position. The system involved is relatively complex, which is not suitable for the construction environment with multiple dust and dark light in coal mine. In the early stage of the project team, the way of mechanical limit was tested, but the effect was not ideal. The main reason was that the limit parts were easy to be damaged, which caused the manipulator movement over range damage. Therefore, a manipulator positioning system based on position sensor is developed.

2.1.2. The gripper
The gripper consists of a front gripper, a rear gripper and a swing cylinder. The front gripper is mainly composed of two clamping oil cylinders, an upper clamp arm, a lower clamp arm and a rotary arm to clamp and rotate the drill pipe. The rear clamp is mainly composed of two clamping cylinders, an upper clamp arm, a lower clamp arm, etc. When the drill pipe needs to be unscrewed, the rear gripper clamps the rear drill pipe to make it fixed, the front gripper clamps the front one, and the swing cylinder drives the rotating arm on the front gripper to swing and rotate in the positive direction, so as to unscrew the drill pipe.

![Figure 3. Gripper.](image)

2.1.3. The crawler
The crawler is the carrier of the whole drilling rig. The pump station is the power source of the whole drilling rig, so that the crawler could be driven by the hydraulic motors which can provide certain climbing power. The central revolving platform can meet the requirements of azimuth adjustment, which has a rotating range of 360°.

![Figure 4. Crawler.](image)

2.1.4. The explosion-proof remote control operation system
Because of the danger of gas explosion in the field of the drilling rig, the explosion-proof remote control system is used to operate the drilling rig remotely. It is mainly composed of an explosion-proof electric control box, an explosion-proof operation box, a pilot solenoid valve, sensors, etc. The explosion-proof operation box is connected to the explosion-proof electric control box. All kinds of
sensors, including hydraulic sensor, power head position sensor, manipulator position sensor and gas parameter sensor, are installed on the corresponding positions of the drilling rig to realize the field data collection. The explosion-proof operation box is equipped with a display screen, various electric control handles, power switches, etc. The data collected by the sensors are showed on the screen, so it is convenient to observe the status in real time. The analog or digital signal of the electric control handle is converted by the explosion-proof electric control box and then transmitted to the pilot solenoid valve, so as to control the hydraulic control multi-channel reversing valve and realize the remote control of the drilling rig.

2.2. Working Principle of Remote Control of Drilling Rig

The long-distance automatic control drilling rig in coal mine is based on the common ones, and the corresponding automatic control module is configured according to the needs, so as to realize various automatic control functions. The working parameters, process status, video image and scene sound of each link of the drilling rig are monitored in real time through all kinds of sensors and video cameras. The data, sound and image can be transmitted in real time through the broadband network of the monitoring system.

Through the existing monitoring system network of the mine, the main machine and its actuators are controlled by remote control station, integrated monitoring system, main control station and hydraulic system. Because of it, the drilling rig can realize the functions of automatic drilling, automatic drill pipe loading and unloading in the angle range of 0 ~ + 90 °, self-adaptive anti-sticking and automatic drilling depth recording. Additionally, the remote control system is designed in a modular structure. Different functions can be added as required, such as underground remote control, ground remote control and so on.

The ground control station controls the controller of the drilling rig through a signal line, and the status, sound and video of the drilling rig can be displayed on it. The command from the ground control station is sent to the main control station of the underground drilling rig through the existing network of the coal mine, in order to achieve the automatic loading and unloading pipes, rotation, propulsion, etc.

The remote control schematic diagram is shown in Fig.5.

![Remote control Schematic diagram](Image)

Figure 5. Remote control Schematic diagram.
3. Working Principle of Remote Control of Drilling Rig and Key Technology

3.1. High Angle Automatic Drill Pipe Loading and Unloading Technology
A combination structure of manipulator and storage box is adopted to load and unload drill pipes automatically in the angle range of 0 ~ + 90°. The high-pressure oil drives the hydraulic motor, oil cylinder and other actuators on the manipulator to grasp, transport and adjust the angle of the drill pipe.

3.2. Automatic Moving and Anchoring Technology
Remote control moving is realized by camera cooperated with ultrasonic distance meter. Pressure sensor is installed on the oil cylinder to measure the anchoring state which will be adjusted automatically when the measured pressure value is lower than the set value of the hydraulic system.

3.3. Automatic Positioning Technology
The attitude meter is developed, which can measure the azimuth and the inclination of the frame of the drilling rig and feed them back to the electric control box in real time. The hydraulic motor on the crawler and the angle adjusting cylinder are controlled by the control program to adjust the azimuth and the inclination of the frame.

3.4. Drilling Parameter Acquisition, Display and Storage Technology
Functions including automatic calculation of drilling depth, acquisition of drilling angle, pressure and other parameters are achieved. Parameters are not only displayed on the screen in real time, but also automatically stored for the hole inspection and the later reference.

4. Application Effect
The field industrial test was carried out in Fengchun coal mine of Songzao Coal-Power Group, Chongqing, China. The drilling angle was 18.5° ~ 50.1°, 29 holes were drilled in total, the hole diameter was 94 mm, the total footage was 3192 m, and the maximum hole depth was 167 m, which improved the automation degree of gas drainage drilling construction and reduced the number of field construction workers in a single shift from 4 to 1-2. The upgraded wireless remote control automatic drilling rig was popularized and applied in Huainan demonstration mining area, drilling 57 holes with a total footage of 3812 m. The overall construction efficiency is the same as that of traditional drilling rigs with the same power. The technical achievements of the all-directional rack automatic adjustment system and the attitude measuring instrument have been applied to ordinary drilling rigs, with remarkable results.

The field application was carried out in Xieqiao coal mine, Huainan Mining Group. The maximum daily footage was 260 meters, and the maximum monthly footage was more than 5000 meters. The monthly footage of a single machine exceeded that of the traditional rig with the same power at the same working face. It is showed by the field test and application that the structure of the remote control drilling rig is designed reasonably, the picture and the sound are fed back clearly by the video and sound monitoring system, the ground and remote control operation system is stable and reliable and operates accurately, the automatic moving, anchoring and positioning functions are accurate and reliable, the automatic drill pipe loading and unloading function acts accurate and stable, and the automatic drilling and withdrawing efficiency is high.

5. Summary
(1) The automatic drill pipe loading and unloading function is realized by the application of the manipulator on the coal mine drilling rig, cooperating with the drill pipe box. Traditional manual operation is replaced by the mechanism, so the labor intensity of the operator is greatly reduced.
(2) Because of the development of the automatic drilling control program, the automatic operation of the drilling rig is realized and the technical guarantee is provided for the efficient and safe production in coal mine.
(3) The long-distance control and even the ground control of the drilling rig is realized with the application of the remote control technology in the drilling rig. As a result, the safety of the operators is guaranteed and the unmanned drilling construction is realized.

(4) It provides advanced technology and equipment for coal mine drilling construction, and solves key problems such as automatic drilling, automatic moving machine, automatic anchoring, automatic positioning and automatic loading and unloading drill pipe with large inclination. Its application will play an important role in remote control drilling construction in coal mine, and can promote the reduction and efficiency, and achieve unmanned operation truly. It can prevent the accidents such as coal and gas outburst, reduce casualties, and ensure the safe production effectively.

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