Development and Test of Rubber Wheel Full Hydraulic Drill in Coal Mine

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Abstract. In order to solve the problem of moving rig quickly and reducing labor intensity in the mine face with trackless transportation conditions, a solution of rubber wheel drill which meets the working conditions is put forward. The drilling rig adopts the configuration of double power and double system, the power comes from the engine when moving, to achieve walking, steering, braking and temporary stability, relocation and transfer of high efficiency and flexibility, the power comes from the motor when drilling, to achieve rotation, feed and auxiliary Angle adjustment, safe and pollution-free construction. After the assembly and debugging of the whole machine, ground simulation test and underground industrial test were carried out on the rig. The test results show that the rig has strong maneuverability, one person can complete the moving walking, the maximum walking speed is 20km/h, and the steering is flexible and the braking is safe. The maximum depth of drilling hole construction is 318m, the target area hit rate reaches 77.8%, the working performance is stable, the hydraulic system is stable, and all parameters meet the design requirements. The equipment provides new technical equipment for the mine drilling construction with trackless transportation conditions.

Keywords. Rubber Wheel Rig, full hydraulic drilling machine, dual dynamic dual system, trackless transport.

1. Introduction
At present, gas extraction drilling rigs in underground coal mine are mainly hydraulic crawler type, which generally consists of crawler chassis, main engine, pump station, control platform and other parts. Compared with traditional split drilling rigs, crawler drilling rigs have shorter movement and stabilization time, which reduces labor intensity of workers [1-5]. However, the long distance moving of crawler drill in the underground still adopts crawler self-propelled, integral moving and disassembled moving and reassembly methods, especially in the mine with trackless rubber wheel transportation and auxiliary moving conditions, which restricts the production and transportation efficiency of the mine. At present, several commonly used relocation methods have the following problems in using:

High intensity of workers: when the drilling rig is displaced for a long distance, when it moves for a certain distance, the cable should be switched to the control electric cabinet, and more than ten workers should be relied on to drag the cable, so repeatedly, until it reaches the drilling field;

Destruction of roadway pavement: cement pavement is laid from the mine mouth to the working face of the drilling field. When the track is walking, it will damage the cement pavement to a certain extent.

In recent years, the trackless transportation infrastructure increases with the mining depth of coal mines, and the country pays more attention to the safe and efficient production of coal mines. The
contradiction between drilling and excavation becomes more prominent, and demands are put forward for fast and convenient relocation of drilling RIGS, low labor intensity of workers and high construction efficiency [6-9]. In view of this demand, the author's project team carried out the development of rubber wheel full hydraulic drilling rig combined with the actual working conditions of underground roadway.

2. The General Research
In the process of development, the theory and method of gas extraction in underground coal mine is applied to solve the overall structural layout and auxiliary equipment of rubber wheel drill aiming at realistic tunnel conditions and working conditions, so as to expand the scope of application of equipment as much as possible while meeting the personalized needs of special users [10]. According to the investigation in many aspects, the whole machine adopts double power double system integration compact layout structure design, when moving, mainly by the walking power cabin (by explosion-proof diesel engine and hydraulic oil pump composition) to provide power, independent walking, relocation convenient; When drilling, it is mainly powered by the working power cabin (composed of explosion-proof motor and hydraulic oil pump), which is safe, reliable, quiet and environmentally friendly. The machine layout is flexible, high efficiency and low labor intensity. It is mainly composed of walking control room, walking power cabin, rubber wheel chassis, working power cabin, working control console, main engine and stabilizing device, as shown in figure 1. Technical parameters of drilling rig are shown in table 1.

![Full hydraulic drill structure drawing](image)

**Figure 1.** Full hydraulic drill structure drawing.

| Component parameter          | Target value |
|------------------------------|--------------|
| The torque /Nm               | 3500~900     |
| Rated speed /r/min           | 65~260       |
| Feed and pull force /kN      | 85           |
| Feeding Stroke /mm           | 1250         |
| Azimuth /°                   | 0~360        |
| Pitching Angle /°            | -90~+90      |
| The weight /kg               | 15000        |
| Maximum speed /km/h          | 15           |
| Maximum gradeability /%      | 27%          |
| Minimum turning radius /m    | 7            |
| Minimum clearance /mm        | 180          |

**Table 1.** Main performance parameters.
2.1. Rubber Wheel Chassis

The coal mine roadway environment complex, often have water, potholes, and difficult to remove anchor [11], require iron chassis with sufficient mobility, according to the above requirements, a narrow postures of general roller chassis is developed, as shown in figure 2, the power comes from the transformed through explosion-proof diesel engine, diesel pause from abroad well-known manufacturers, after coal security certification, To meet the emission requirements of mining diesel engine, the volume speed regulation system composed of variable hydraulic pump and variable hydraulic motor is selected. By adjusting the displacement of hydraulic pump or hydraulic motor to adjust the speed or torque of the motor, the stepless speed regulation of multi-wheel group is realized. The maximum traction force and braking force are 45 kN and 80 kN.

The frame is composed of 2 main beams and a number of beams, all using low alloy structural steel Q345, has the characteristics of high strength, large bearing capacity, the main beam along the longitudinal according to the layout of the design of different interfaces, other parts of the drill are connected with the main beam through high strength bolts. The middle and side of the main beam are designed with the cable bayonet, which is convenient for the layout of pipes and cables, and improves the aesthetics and maintenance. The control operation valve and button of the whole machine are installed in the cab, and the cab is customized by professional manufacturers. See figure 2.

![Figure 2](image)

1-Walking cab; 2-Walking power cabin; 3-Hydraulic oil tank; 4-Fuel tank; 5-Tyre; 6-Transmission box; 7-Frame; 8-Leg

Figure 2. Structure of rubber wheel chassis.

2.2. Host Structure Design

The main machine is composed of multi-cylinder compound lifting device, feed device, gyroscope and gripper, etc. The whole machine is arranged at the rear of the rubber wheel chassis, and the orientation can be adjusted within the range of -90°~+90°, as shown in figure 3.

![Figure 3](image)

1-The rotary; 2-Feed device; 3-Multi-cylinder compound lifting device; 4-Holder

Figure 3. Working host structure diagram.
Through symmetrical arrangement of hydraulic cylinders and rotary support, the multi-cylinder composite lifting device can achieve a wide range of adjustment of the horizontal opening height (1.75m~2.55m), the distance between the opening and the hole mouth, and the tilt Angle (-90°~+90°), as well as achieve the stability of the main engine during work, and realize the drilling construction of various tilt angles in the whole section of the roadway. Improved rig reliability and safety. Feeding device is mainly used in the reciprocating movement of the gyrator, consists of fuselage, give the oil cylinder and the plate, on which the design of gyrator and holder, spindle hole structure is used to gyrator (phi 110 mm diameter) of the gear box and the normally open type hydraulic clamping structure, cooperate on open normally closed type holder (maximum by phi 150 mm in diameter), It can meet the requirements of construction conditions and dealing with accidents in holes.

2.3. Work Control Platform Design
Console is the control unit of drilling rig, is composed of hydraulic control valve, pressure gauge and pipe fittings, main control rotary drilling rig, such as feed movement of the actuator, the console can rotate using two levels of structures, by post and u-shaped arm rotating respectively, convenient operating personnel to observe hole, operators can also remove control board, The operator can remotely operate the rig by standing within a safe range or in an area where the hole location is easier to see, as shown in figure 4.

![Figure 4. Working control board structure diagram.](image)

1-Secondary jib; 2-Rack; 3-Control handle; 4-Display instrument; 5-Swivel lock; 6-Turning arm; 7-Pillar

2.4. Matching Design of Mud Pump Unit
In drilling rig construction, mud pumps are mainly used to provide stable high-pressure fluid flow, drive the screw motor at the bottom of the hole to rotate the chips, and at the same time have the function of flushing the rock (coal) powder in the hole, cooling the drill bit and protecting the hole wall [12, 13]. Mud pump output capacity and properties affect the drilling construction efficiency, in order to meet the needs of the construction, through the analysis of the characteristics of the slurry pump input and output, the optimized design input torque rotate speed, the corresponding relationship between the output pressure and flow through matching hydraulic pump, multi-way valve, controller and motor as input control chain of mud pump, and optimize the output pipeline design, Realize the remote stepless control mud pump output flow and pressure, so that its maximum output flow and pressure are 260 L/min and 9 MPa respectively.

3. Hydraulic System Design
The working condition of rubber drilling rig is mainly composed of two parts: relocation and drilling construction. According to the needs, a full hydraulic operating system is designed to adapt to the working condition. The execution action of the stable part can be respectively driven by two kinds of power cabin to improve the convenience and adaptability.
3.1. Hydraulic Control System Design for Relocation

Move the hydraulic system are mainly drive, steering and braking system of three aspects, including drive adopts hydraulic closed drive control system, is composed of the beginning and the end of the hydraulic pump and motor are connected, and design the oil compensating device and flushing device, the vast majority of the hydraulic oil between the pump and motor cycle, suitable for big external load inertia and reversing frequent institutions, In particular, the drive system of compact equipment [14-16] is more suitable for the working conditions in the roadway.

Steering and braking system is mainly composed of hydraulic pump, steering gear, oil cylinder, filling valve, brake pedal and brake. Full hydraulic steering is safe and flexible, the braking system is mainly divided into parking brake, service brake and emergency brake three parts, in the drive axle is equipped with normally closed wet multi-disc brake, when driving, pressure oil overcomes the spring force to open the brake; Stop, the brake pressure relief, under the action of the spring force, parking brake; Crane brake, which make use of closed system, when the driver loosen the accelerator pedal, the displacement of variable pump is gradually reduced to 0, decreases in the system of circulation flow in the pipeline between the motor and pump to produce high pressure oil pipe, high pressure relief valve in the pump I work, produce the effect of hydraulic damping, realization of vehicle braking, as well as on the crane brake pedal. The pressure oil enters the brake oil chamber through the brake pedal and pushes the piston to press the friction plate to achieve braking. When the driver releases the brake pedal, the pressure oil flows back to the oil tank through the foot pedal to relieve pressure. After pressure relief, the return spring springs back the friction plate [17, 18]. Emergency braking is mainly achieved by the red button in the walking control room. The staff beside the drilling rig can also pull the emergency handle placed on both sides to close the engine and achieve emergency braking.

3.2. Design of Hydraulic Control System for Drilling Construction

As shown in the hydraulic system used for drilling, the double-pump open circulation system with load sensing variable control mode is adopted to improve the negative situation that may occur when the rotary load of drilling rig changes frequently. It is composed of rotary loop, feed loop and auxiliary function loop [19]. Including rotary circuit composed of hydraulic variables pump and hydraulic motor speed control system can be stepless speed regulation, rotational speed and torque can be adjusted at the request of different working conditions in the larger scale, make the rig drilling technology has strong adaptability, automatic clamping tool when turning, inversion of automatic clamping holder, improves the operation convenience and security; Feed circuit is mainly used to provide drilling feed force, pulling force, can be in remote control handle and under the action of the reversing valve, realize the drill fast and slow feed pulling, rotation and feeding circuit under the action of mutual cooperation, realize the drilling tools and drilling of composite action, according to the chuck of the directional control valve control and gripper, form a complete set of drilling technology to realize pressure drilling; The auxiliary circuit is mainly composed of hydraulic pump, multi-link control handle and actuator to achieve the stabilization of the rig, adjust the Angle of the fuselage and azimuth Angle, etc., in order to adapt to different drilling needs.

4. Test in Field

After the drilling rig was developed, according to GB3836, MT/T 790-2006, MT/T 989-2006 and other standards, a comprehensive test was carried out in The National Safety Production Xi’an Exploration Equipment Testing and Inspection Center, including the weight of the whole machine, maneuvering performance and rotary performance, as shown in figure 5. The weight of the whole machine was 14,600 kg. Maximum driving speed is 20 km/h, maximum climb is 27%, turning radius is 6.8 m, and ground clearance is 180 mm. When the rotation capacity is 3500 Nm, the speed is 70 r/min; when the rotation capacity is 932 Nm, the speed is 266 r/min, which meets the design requirements.
The underground industrial test was carried out in Shendong Buertai Coal Mine of China National Energy Group. Combined with the production situation, it lasted for 3 months and carried out the relocation test and the water drilling test in the goaf respectively. In the relocation test, the accumulated driving is more than 80 km, and the maximum walking speed reaches 20 km/h, which requires one person to complete the operation. Thirteen test holes were completed with 100% success rate. The cumulative footage was 1990m, the maximum hole depth was 318 m, the maximum elevation Angle was 85°, and the maximum depression Angle was -90°. There were 9 directional holes, 7 of which were connected with the goaf, the hit rate was 77.8%, and the average footage was 35 m/shift.

(a) Climbing test  (b) The factory inspection

**Figure 5.** Field test photos.

5. Conclusions
Through the design and experiment of rubber wheel full hydraulic drill, the requirement of fast moving drill and reducing labor intensity put forward by coal mine is met.

1) The wheel chassis of the drilling rig is designed to solve the problem of rapid relocation, and the explosion-proof diesel engine is used to provide power and improve the maneuverability and operation efficiency. Combined with the development of the selected drilling tools and construction technology, the requirements for the construction of water probe holes are met.

2) In order to improve the scope of application of equipment, we can carry out technical research on auxiliary driving and electro-hydraulic control system in coal mine, further reduce the size of the whole machine, and combine with remote control technology to achieve the purpose of remote control of drilling rig.

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