Development of Intelligent Wellhead Platform for Rescue Truck-mounted Drilling Rig

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Abstract. In view of the low efficiency of rescuing trapped people in coal mine accidents, the factors affecting rapid drilling are analyzed. Through the modular and intelligent technology of rescue vehicle drilling rig, a kind of intelligent wellhead platform drilling tool is developed. The wellhead platform has the functions of automatic levelling and automatic screwing and unloading of drilling tools, and realizes the efficient centering, clamping and automatic screwing and unloading functions of all kinds of diameter drilling tools. The automatic levelling of the intelligent wellhead platform adopts the closed-loop control strategy, the dynamic automatic levelling of the wellhead platform, and the automatic screwing and unloading device adopts program control, which realizes the automatic unloading of drilling tools with one button. The intelligent wellhead platform can be quickly assembled with the main engine, saving drilling auxiliary time, and is of great significance for underground rescue in coal mines.

1. INTRODUCTION
Coal mining is accompanied by various disasters, such as mine water inrush, mine fire, gas explosion, dust explosion, coal and gas outburst. These disasters are the main factors for the frequent occurrence of coal mine accidents [1-3]. In recent years, the state has increased its investment in coal mine safety, and coal mine accidents have been greatly reduced. However, according to relevant statistics, the mortality rate of millions of tons of coal mines in China is still higher than that in developed countries, and coal mine accidents of different degrees still occur from time to time [4-5]. After the coal mine accident, the original evacuation roadway was deformed or blocked, and the trapped miners and rescue workers could not get through smoothly [6]. In order to carry out rapid rescue, large diameter boreholes are widely used to build escape channels and rescue material support channels to rescue trapped miners. At present, the construction of large diameter drilling is realized by surface emergency rescue rigs through rapid drilling technology combined with measurement while drilling technology [7]. Any large diameter drilling must focus on safe and efficient drilling, and improve drilling efficiency through technical innovation and improvement of supporting equipment. Especially when used in coal mine rescue, it can provide solid and reliable technical support [8-9]. Intelligent wellhead platform rescue of vehicle-mounted drilling rig is a key component of vehicle-mounted drilling rig, and its performance and reliability directly affect the construction efficiency. In view of the fact that the wellhead of the vehicle-mounted drilling rig is difficult to meet the needs of large-diameter drilling, an innovative design is carried out, and the automation level is greatly improved.
2. Overall scheme of intelligent wellhead platform
The overall scheme of the intelligent wellhead platform shown in figure 1 mainly includes the following parts:

![Figure 1 The intelligent wellhead platform](image1)

(1) The U-shaped wellhead platform with real-time monitoring and automatic levelling function has a bearing capacity of 120t. The overall structure size is small, the opening diameter is large, and the wellhead platform and the drilling rig girder are connected by a pin, which is fast and reliable. The wellhead platform automatically adapts to the central position of the wellhead of the power head and aligns in real time.

(2) The hydraulic chuck can meet the clamping and passing of multi-specification drilling tools by replacing different slip combinations.

(3) The wrenching clamp assembly (one-button unloading drilling tool) with manual and automatic double control function has the advantages of small overall width and large diameter range of makeup and breakout device, which can meet the technological requirements of traditional drilling and hydraulic lifting drilling.

3. Overall scheme of intelligent wellhead platform
The overall scheme of the intelligent wellhead platform shown in figure 1 mainly includes the following parts:

3.1. U-shaped mechanical platform

![Figure 2 The U-shaped mechanical platform](image2)
As shown in figure 2, the U-shaped mechanical platform adopts modular design, bottom warping combined with frame four-leg structure to realize rapid installation with the main engine of the drilling rig. The wellhead platform is supported by four legs, which is mainly composed of hydraulic legs, mechanical frame and detachable patching. The hydraulic leg is composed of four hydraulic cylinders with self-locking function, which can adjust the height of the mechanical frame. The mechanical frame adopts section steel welding, which meets the load-bearing requirements of drilling tools in the well and has sufficient strength and stiffness.

3.2. Mechanical system of shackle pliers

![Figure 3 The shackle pliers assembly](image)

Figure 3 shows the shackle pliers assembly, and the base is the base of the back clamp, the punching clamp (the main clamp) and the fastening clamp, which is used to clamp drilling tools, which can realize the horizontal and vertical movement of the clamp head and bear the reverse torque of the fastening pliers. The base adopts the form of double guide rail, which can not only realize the overall movement of the release clamp assembly, but also realize the individual movement of the buckle clamp. The punching clamp and the back clamp drive the V-shaped tooth plate to clamp the drilling tool joint through two cylinders respectively. The upper buckle and punch process of the drilling tool is completed by the rotation process of the buckle clamp driven by the buckle cylinder. The buckle clamp uses a hydraulic cylinder clamp and a buckle motor to drive the roller slider to realize the buckle action. The buckle clamp can move along the vertical direction to compensate the vertical displacement of the drilling tool and reset the spring.

| Parameter                  | Value          |
|----------------------------|----------------|
| Clamping drill tool range /in | 2 7/8-10      |
| Maximum screw on torque /kN m   | 80             |
| Maximum punching torque /kN m   | 100            |
| Turn-lock clasp speed /rpm      | 80             |
| Overall movement distance /mm   | 1000           |
| Spinner pliers movement distance /mm | 500         |
| Vertical movement distance /mm  | 500            |
| Operating mode                | manual, automatic |
4. Intelligent wellhead platform control system

4.1. Hydraulic control system of intelligent wellhead platform

The automatic wellhead platform adopts full hydraulic control mode, and the hydraulic system is shown in figure 4. The system mainly includes the automatic levelling system of the wellhead platform and the hydraulic system of the automatic unscrewing device. In the automatic levelling hydraulic system, the pressure oil pumped by the constant pressure variable pump enters the working oil port of each valve in the multiple proportional valve through two identical shunt collecting valves, which is respectively connected with the controlled double-acting hydraulic cylinder. The hydraulic cylinder has its own hydraulic lock with self-locking function to ensure that the hydraulic cylinder is reliably self-locked in the case of power outage, and the hydraulic cylinder is hinged and connected with the wellhead platform. Before the platform rises to the specified height, each spool of the proportional valve is in a fully open position, and each hydraulic cylinder rises rapidly synchronously. When the wellhead platform reaches the predetermined position, each spool of the main valve can work independently according to the controllable setting program, and independently control the flow into the rodless cavity of the cylinder until it reaches the set position. The hydraulic system of the automatic unscrewing device mainly includes the hydraulic system of the buckle clamp, the hydraulic system of the buckle clamp and the hydraulic system of the base. The hydraulic system of buckle clamp is composed of three hydraulic subsystems: back clamp clamp, buckle clamp clamp and cylinder buckle hydraulic system. During the clamping process of back clamp and buckle clamp, the clamping force is required to be stable, and the pressure adjustable two-way balancing valve is used to control the clamping force in the two systems respectively. According to the requirements of operating conditions, the clamping force can be adjusted. The hydraulic system of the buckle cylinder requires smooth expansion, accurate position and fast buckle speed, and the system adopts the design of magnetostrictive cylinder. In the rotary buckle clamp hydraulic system, four cycloidal motors with brakes are adopted, the four motors are designed in parallel, and the brake oil cylinder of the hydraulic motor is controlled by shuttle valve and spring. When there is pressure on one side of the motor, the high pressure oil enters the brake cylinder through the shuttle valve, opens the brake, and the motor runs normally; when the control valve is in the middle, the hydraulic oil of the brake cylinder releases hydraulic oil, the brake clamps the motor shaft, and the motor stops working. The hydraulic system of the base is controlled separately by hydraulic cylinder and control valve to realize the horizontal and vertical movement of the whole punching device.

![Figure 4 Hydraulic system of intelligent wellhead platform](image-url)
4.2. Electrical control system of intelligent wellhead platform

4.2.1. Levelling electric control system of wellhead platform

The levelling system consists of three parts: detection, actuator and control system, including biaxial inclination sensor, valve-controlled hydraulic cylinder, digital hydraulic control system based on mobile vehicle controller and related connection cables. The main results are as follows:

1) the sensor of the detection device adopts the biaxial inclination sensor and the pressure sensor, and the inclination sensor is used to detect the unevenness of the wellhead platform. The detection value is the basis for the system to judge whether it is levelling or not, and its detection accuracy affects the levelling accuracy of the system. The pressure sensor is used to detect whether each leg has a broken leg and whether the pressure is too high, so it is easy to adjust the opening size of the corresponding solenoid valve.

2) The levelling actuator adopts four hydraulic legs with self-locking function, which are symmetrically arranged on both sides of the wellhead platform and controlled by the corresponding electro-hydraulic valve. Through the up and down expansion of the leg, the levelling of the wellhead platform is realized.

3) The control system is the core component of the automatic levelling system. The control system takes the controller for the mobile vehicle as the core. By detecting the angle of the platform and the pressure of the hydraulic leg, and then through the closed-loop automatic control algorithm to complete the extension or retraction control of the hydraulic leg to complete the automatic levelling of the wellhead platform. The schematic diagram of the control system is shown in figure 5.

![Figure 5 Schematic diagram of the electronic control system of split table leveling](image)

4.2.2. Wellhead platform levelling software system

When the automatic levelling processor receives the data sent by the horizontal sensor, the first step is whether the wellhead platform is horizontal or not. If it is uneven, the calculation is carried out to determine the next operation, and then a control instruction is issued according to the calculation result, which is repeated until the levelling is finally reached. The software block diagram is shown in figure 6.

![Figure 6 Flow chart of automatic levelling software](image)
The levelling control process is a fuzzy logic control process, its basic idea is to take the highest point as the benchmark, the other points gradually rise to approach it, and finally reach the level, the levelling flow chart is shown in figure 3. The algorithm design of the levelling software adopts the method of simulating manual levelling, first sampling the data of the horizontal sensor, then judging which bracing leg needs to be adjusted, and then sampling the horizontal sensor again after the adjustment, and then judging again which bracing leg needs to be adjusted. This is repeated until the final levelling.

5. Debugging of Electro-hydraulic Control system of Intelligent wellhead platform

After the assembly of the wellhead platform, the electro-hydraulic control system is debugged. In the process of debugging, we test with on-off valve and proportional valve respectively, and the measurement results are shown in Table 2.

| Project | Proportioner valve | switch valve |
|---------|-------------------|--------------|
| precision accuracy /° | 0.03 | 0.06 |
| levelling time/s | 2 | 2.8 |

It can be seen from Table 2 that the on-off valve can reach 0.06 ° and the automatic levelling time is 2.8 seconds. The proportional valve can be used to achieve 0.03 °, and the levelling time can be shortened to 2 seconds. Therefore, the scheme of proportional valve not only has high precision, but also reduces levelling time and high efficiency.

6. Conclusion

The intelligent levelling wellhead platform fully considers the requirements of rescue construction technology for drilling tool grading and site adaptability, and adopts modular design with a maximum diameter of 930mm to meet the requirements of large diameter bit and casing; the intelligent levelling control system solves the problem of continuous horizontal state of the wellhead platform and ensures that the drilling trajectory is not skewed in the drilling process. The drilling tool fast unscREWing device, the maximum shackle torque reaches 100kNm, and the maximum drilling tool diameter reaches 900mm. The quick unloading device adopts automatic control program, which can realize the modular assembly structure of the one-button screwing and unloading drilling tool wellhead platform, which greatly saves the installation time of the equipment and provides the rescue efficiency.

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