Development and Application of the RCD Dynamic Simulation Test Equipment

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Abstract. As the most important wellhead control equipment to implement underbalance/gas drilling and managed pressure drilling, the quality and reliability of rotating control device (RCD) will directly affect the safety and efficiency of the drilling operation. In order to conduct the RCD performance test, maintenance and the new RCD product research and development, the RCD dynamic simulation test equipment is developed. This equipment is mainly composed of mechanical transmission system, hydraulic system, electrical control system, data acquisition and processing system, remote monitoring and control system, which has reasonable structure and enough functions to satisfy the requirements. According to the GB/T 25430-2010 and API 16 RCD, the experimental results show that the equipment can meet the RCD test requirements under various operating conditions. The test equipment can not only test the reliability of the RCD, but also can provide experiment basis to research and develop the new RCD.

Introduction

No longer simply a flow diverter, the rotating control device (RCD) is a key piece of well control equipment and one of the most important instruments in underbalanced/gas drilling and managed pressure drilling applications\cite{1-3}. During the drilling process, the RCD can not only seal the drill pipe or kelly but also maintain them rotating under a reliable wellhead pressure condition. During the other snubbing operations, such as snubbing tripping, the RCD can maintain a tight seal for the annulus and allow specified size of drilling tools and tool joints to pass through. Thereby, the reliability of RCD directly affects the safety and efficiency of the drilling operation. In order to ensure the reliable performance of RCD, the corresponding testing and detections must be conducted prior to the field service. Based on the related requirements in GB/T25430-2010\cite{4}(Specification of Drill Through Equipment - Rotating Control Devices) and API Spec 16 RCD\cite{5} (Specification of Drill Through Equipment - Rotating Control Devices), the RCD dynamic simulation test equipment is developed\cite{6-7}. The experimental results show that the equipment can meet the RCD test requirements under various operating conditions, such as machine strength test, static seal test, dynamic seal test, and the results are very well.
**Structure Principle of the Equipment**

The RCD dynamic simulation test equipment is mainly composed of mechanical transmission system, hydraulic system, electrical control system, data acquisition and processing system, remote monitoring and control system. When carrying out dynamic simulation test, fixing the flanged base firstly, and then loading and fastening the rotating assembly. Subsequently, inserting the testing drill pipe and connecting it with the live spindle under test turntable. Finally, starting electrical control system to driven the direct-current motor to run, which will motivate the movement of rotary table, live spindle and testing drill pipe through the motor spindle, and then obtaining the performance testing of the RCD rotary motion. Testing drill pipe can move up-and-down by controlling the hydraulic cylinder, testing data can be collected in time and parameters can be adjusted simultaneously by data acquisition and processing system, which can simulate various operating conditions.

**Mechanical Transmission System**

The main functions of mechanical transmission system are to support rotary table, live spindle, load hydraulic cylinder, and thereby transmit the force loaded by the motor and hydraulic cylinder to testing drill pipe. The live spindle and loaded hydraulic cylinder are fixed on the cuboid stents of four stand columns, and the rotary table is installed on the middle of horizontal junction plates. Meanwhile, the mechanical transmission system also needs to bear the pressure cylinder load and provide the necessary test load pressure. In order to make the operation of test process easy and reserve enough space for function expansion, a pit under the test-bed is designed. The length, width and depth of the pit are 9 meters, 5 meters, 5 meters respectively. There are horizontal thrust hydraulic cylinder, orbit and wellhead flange in the pit for the purpose of installing the RCD specimen conveniently. The mechanical transmission system has advantages of compact structure, rational layout, convenient to use, et al.

**Hydraulic System**

The hydraulic system is mainly used to control the movements of loaded hydraulic cylinder, horizontal thrust hydraulic cylinder, and vertical pressurized hydraulic cylinder, and the schematic of this system is shown in Fig.2.

![Figure 1. Structure of the mechanical transmission system.](image-url)
As the hydraulic pump started by AC motor, the hydraulic oil in tank passes through the filter, oil pump, group valve, accumulator and high pressure oil pipe into non-rod chamber of hydraulic cylinder to push the piston rod in hydraulic cylinder to move downward, which provide the loading pressure to live spindle. While unloading, hydraulic oil enters into the rod chamber of hydraulic cylinder, and then pushes the piston rod back. The utilization of accumulator can increase loading speed and reduce the vibration effect of the dynamic simulation test. The horizontal thrust hydraulic cylinder and vertical pressurized hydraulic cylinder can move the RCD to wellhead and insert the testing drill pipe into the rotating assembly, which guarantee the convenience of the dynamic simulation test.

![Diagram of the hydraulic system](image)

1. hydraulic tank 2. air filter 3. oil filter 4. plunger pump 5. AC motor 6. check value 7. safety value 8. accumulator 9. pressure gauge 10. pressure sensor 11. electro hydraulic reversing value 12. hydraulic locking value 13. loaded hydraulic cylinder 14. horizontal thrust hydraulic cylinder 15. vertical pressurized hydraulic cylinder 16. check valve 17. throttle valve 18. electromagnetic reversing value 19. pressure gauge 20. value 21. spill value 22. oil filter 23. liquidometer

Figure 2. The schematic of the hydraulic system.

**Electrical Control System**

During the testing process, the electrical control system (ECS) mainly controls the start/stop of DC motor and hydraulic pump, the telescopic of loaded hydraulic cylinder, horizontal thrust hydraulic cylinder and vertical pressurized hydraulic cylinder, et al. Meanwhile, by adjusting the rotation speed of DC motor and the size of the cylinder loading pressure, ECS can conduct various simulation tests with RCD under different rotating speed and drilling pressure.

**Data Acquisition and Processing System**

Utilizing the independently programed of the RCD dynamic simulation software, data acquisition processing system can real-time collect and record the following dynamic parameters in the process of the RCD dynamic simulation test, such as drilling pressure, torque,
rotational speed, load, displacement of hydraulic cylinder, pressure of hydraulic system and the shell temperature of the RCD. Due to software can set or change the related moving parameters, so the RCD can perform simulation test under different conditions, which has a high ability of remote control and automation.

**Remote Monitoring System**

RCD dynamic simulation belongs to high pressure experiment, and the working pressure reach as high as 70 MPa. During the testing process, in order to monitor the leakage of key parts, utilizing the HD camera and video acquisition card to real-timely monitor the operation condition of every equipment, so as to ensure the safety of test personnel.

**Main Technical Parameters and Function Introduction**

The main technical parameters of RCD Dynamic Simulation Test Equipment are shown in Table 1.

| Maximum static pressure MPa | Maximum dynamic pressure MPa | Maximum pipe working stroke mm | Rotary speed r/min | Maximum torque N·m | Maximum load stress KN |
|-----------------------------|-----------------------------|--------------------------------|--------------------|---------------------|-----------------------|
| 105                         | 35                          | 2000                           | 0—220              | 7000                | 800                   |

According to the requirements of GB/T25430-2010 and API Spec 16 RCD, the main technical parameters of this RCD dynamic simulation test equipment can not only conduct the highest pressure level test of the existed RCD, but also can meet the RCD test requirements under various operating conditions, such as static pressure rating test, dynamic pressure rating test, packer access test, stripping life test. Meanwhile, this equipment also can carry out the functional test of the well blowout preventer and downhole tools.

**Application**

Using this equipment, the XF series active RCD and RCD of type XK-21/35(220) have successfully developed. Taking the RCD of type XK-21/35(220) test for example, the following tests are conducted on the trip, which are shell strength test, static pressure rating test, dynamic pressure rating test, packer access test, stripping life test. During the shell strength test, there is no leakage happens while injecting water into the pressure testing hole until pressure reach 53.6 MPa and maintaining the pressure for 15 minutes. When taking the static pressure rating test, a diameter of 5 inch rubber core installed in the rotating assembly is used to seal theφ127 mm testing drill pipe. There is no visible leakage while pressurizing it to 1.8 MPa and 35.87 MPa respectively and maintaining the pressure for 10 minutes. When conducting the dynamic pressure rating test, control the following injection pressure and rotational speed successively, which are 0 MPa, 30 r/min; 21 MPa, 60 r/min; 17.5 MPa, 90 r/min; 14 MPa, 120 r/min. There is no leakage for the sealing parts when the total test time is more than 200 hours and the surface temperature of bearing is 55 ℃. During the packer access test, there is no leakage while keeping the pressure drop range from 0.23 MPa to 0.74 MPa. Taking the stripping life test with the control tripping speed of 305 mm/s, pressure of 7.0±0.5 MPa and up and down stroke of 1524 mm, and doing the reciprocating motion in the packer
Conclusions

1). The RCD dynamic simulation test equipment can carry out variable tests under kinds of operating conditions with the maximum static pressure of 105 MPa, maximum dynamic pressure of 35 MPa and infinitely variable rotary speed of 0-220 r/min.

2). The RCD dynamic simulation test equipment has features of compact structure, reasonable configuration, convenient operation, high degree of automation and monitoring, and reliable performance.

3). The experimental results show that the test equipment can not only conduct the reliability test of RCD, but also can provide experiment basis to research and develop new RCD.

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