Research on the Hydraulic System of Double Power Heads in Anchor Drilling Rig

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Abstract. In order to solve the problem of mutual interference between the double power heads in anchor drilling rig and improve the efficiency and reliability of the whole machine, a hydraulic system principle diagram of the anchor drilling rig is set up. According to the working principle of the anchor drilling rig, a simplified model is built and studied by AMESim software. Furthermore, the hydraulic system is tested on the simulation test bench. The result shows that when the double power heads operate under no load condition and rated condition, the output flow and pressure are independent and have no influence each other. The field test shows that the rotary and feeding action of the double power heads can meet the design requirements, the stable rotational speed of the power head 1 and the power head 2 are 354.1 r/min and 361.3 r/min respectively, and the stable output torque are 310.2 N·m and 308.5 N·m respectively. The results provide a theoretical basis for the optimization design of the double power heads in anchor drilling rig at the same time.

1. Introduction

In recently years, with the increase of coal mining intensity and depth, the difficulty of the roadway surrounding rock control is increasing day by day, and coal mine safety accidents happen frequently[1-3]. At present, as an effective way of supporting roadway, bolting has become the main support method for mine roadways, it is an indispensable technology for high yield and high efficiency production in coal mine. Bolt (cable) hole drilling is an important link of anchorage support construction, and the construction of directional blast holes along the roof of the roadway can improve the stress environment of the surrounding rock in the roadway. It is an important supporting technology in the retaining roadway (digging) along the roadway. The rapid construction of bolt (cable) hole and directional blasting hole need advanced and reliable drilling equipment to ensure[4-6]. The double power heads type in coal mine anchor drilling rig can be used for the construction of the equidistant directional blasting holes, and can also be used for the construction of the bolt (cable) hole, which is mainly suitable for the conditions of the roadway height of 2.2 m to 3.8 m. This type anchor drilling rig has high construction efficiency, narrow width, strong applicability, precise drilling location and convenient movement. The double working arm can realize full-scale angle adjustment, and can simultaneously construct two holes with equal spacing, and the holes spacing is the divisor of 2400 mm or 2500 mm. The distance of drilling holes covers a wide range, which greatly improves the applicability and operating capability of the device.

To solve this problem that requires double power heads to work at the same time, the traditional hydraulic system usually adopts a combination of two hydraulic pumps, and the two hydraulic pumps respectively provide power to two power heads, which can guarantee the independence of the double power heads and do not affect each other. Due to the compact structure of the anchor drilling rig and the limited space, the conventional double hydraulic pump is inconvenient to install and layout. In this paper, a combination of single pump and multiple LUDV valves is adopted. At present, this type of LUDV hydraulic system has been applied in many devices[7,8]. Because of the different working modes and requirements of the double power heads in anchor drilling rig, on this basis, this paper studies the characteristics of the hydraulic system of the anchor drilling rig systematically and can provide theoretical support for improving the working efficiency and reliability of the double power heads.

2. Design of the hydraulic system

The LUDV hydraulic system is a load independent flow distribution system. This kind system uses the post valve compensation technology. It controls the speed of each actuator by controlling the opening of the load sensitive multiplex valve, but it has nothing to do with the load of the various actuating components. At the same time, the pressure signal of the load can be fed back to the variable pump, the variable pump adjusts its flow rate and pressure in real time according to the pressure signal, so that it adapts to the load demand, when the flow rate of the variable pump is saturated, it can still work normally, which greatly improves the machine's maneuverability[9,10]. When the maximum flow rate that the variable pump can provide is less than the sum of the demand flow of each actuator, the flow to each branch is based on the maximum flow of the variable pump, and is allocated in a positive proportion according to the opening degree of the control valves of each branch. It will not cause the execution organizations to lose the coordination ability of the compound action [11-13]. the double power heads in anchor drilling rig is presented in figure 1.

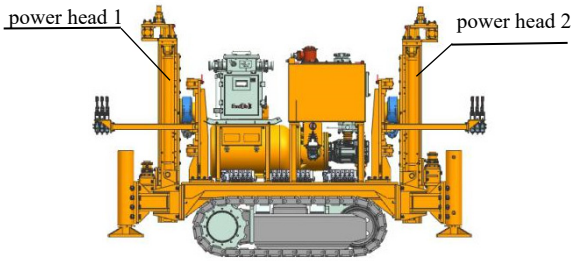


Figure 1. The working mechanism hydraulic schematic diagram.

The hydraulic system of the double power heads in anchor drilling rig is mainly composed of A10VO100 load-sensing variable displacement pumps, three hydraulic LUDV multiplex valves and various actuators. Two LUDV multiplex valves control the rotation, feed, and gripper functions of the double power heads, the other LUDV multiplex valves mainly control the attitude adjustment of the working arm, the stabilization of the legs and the crawler walking. A water-cooled radiator is used and a pilot oil supply is used to provide hydraulic oil to the operating handle. The system is powered by a variable displacement pump with the pressure cut-off and load-sensing control functions. The multi-way valve uses a LUDV multiplex valve with pressure compensation, and the hydraulic schematic diagram of the whole machine is shown in figure 2 .

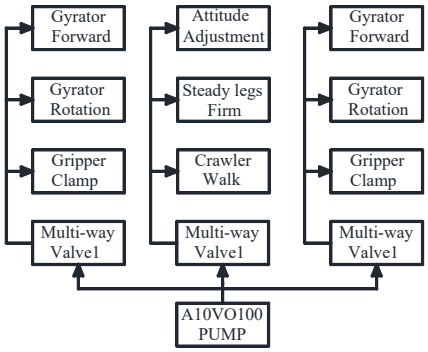


Figure 2. The working mechanism hydraulic schematic diagram.

In order to study the dynamic characteristics of the LUDV hydraulic system, the basic parameters of the anchor drilling rig must be selected. First, the variable pump is selected. The performance parameters of the anchor drilling machine with the same domestic capacity are referred to the A10VO100, the hydraulic pump of BOSCH Rexroth company is adopted. The performance parameters are as follows: the nominal displacement is 100 mL/r and the high pressure is 35 MPa, the shell outlet pressure is 2 MPa, the maximum rotational speed is 2600 r/min, the structure type is the swashplate axial piston pump, according to the specific performance requirements, the motor with 45 kW is considered. Due to the overload capacity of the motor and the appropriate limit of the hydraulic pump when used, the YBK2-225M-4 mine flameproof motor can be selected to meet the requirements of the power.

3. Simulation of the hydraulic system

As the structure of the double working arm of the anchor drilling rig is similar, and the adjustment of the attitude in the auxiliary working arm, the stability of the outrigger and the crawler walking loop controlled by a LUDV multi-way valve are relatively simple. In order to simplify the research problem, this paper simplifies the physical simulation model properly, only needs to study the gyration loop of the double power heads and carry out simulation research. The simulation model is shown in figure 3. By analyzing the working conditions of this anchor drilling rig, the actual application condition mainly includes the empty load and the rated condition. The simulation study is performed by using the simplified AMESim model. The main simulation parameter table is shown in table 1.

Table 1. The main simulation parameter table.

Parameter	value
Motor speed / (r/min)	1470
Variable pump displacement / (mL/r)	100
Hydraulic motor displacement / (mL/r)	130
Hydraulic motor theoretical design flow / (L/min)	60
Pressure cut off / MPa	31.5
Load feedback pressure difference / MPa	1.8

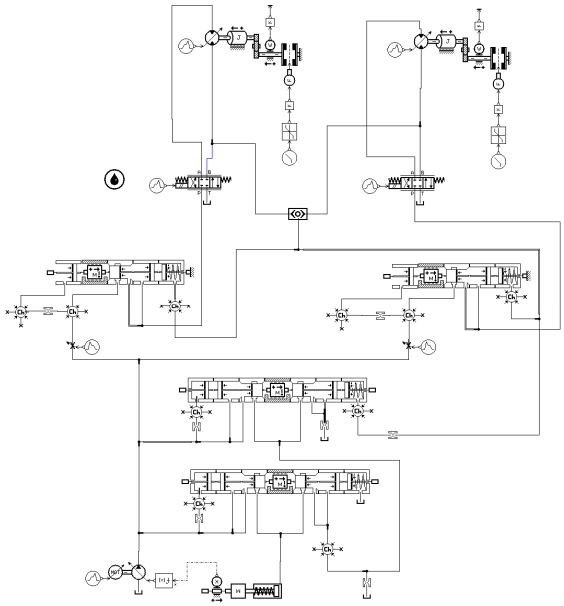
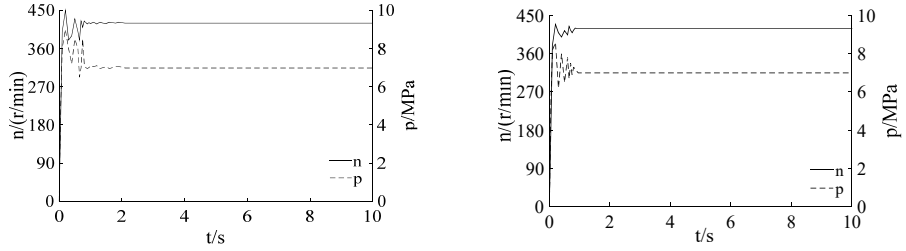


Figure 3. A simplified AMESim hydraulic system diagram.

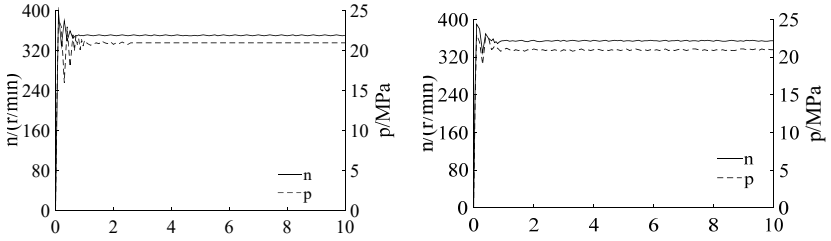
When the sampling interval is 0.1 s and the sampling time is 10 s, the double power heads are rotated at the same time, and the rotating load signals are set to 0 and 1 respectively. Then the system pressure and flow curve under the empty load condition and the rated condition are shown respectively in figure 4 and figure 5 respectively.



a) power head 1 b) power head 2

Figure 4. The No-load condition.

As can be seen from figure 4, this is the empty load condition of the anchor drilling rig. there are a certain degree of fluctuations in the speed and pressure of the power head 1, the final stable speed is 420.4 r/min, the stable system pressure is 6.9 MPa, and the speed and the system pressure of the power head 2 also have a certain wave motion, the final stable speed is 422.3 r/min, the final stable pressure is 7.1 MPa, which reaches the theoretical design data.



a) power head 1 b) power head 2

Figure 5. The Rated condition.

As can be seen from figure 5, this is the rated condition of the anchor drilling rig. the final stable speed of the power head 1 and 2 are 352.4 r/min and 354.1 r/min respectively, and the stable system pressure are 21.5 MPa and 21.9 MPa respectively. At this time, the system pressure of the double power heads reaches the set value, and the speed decreases about 16%. This is because the system

pressure rises to reduce the flow of the system, which leads to the reduction of the speed, but it meets the design requirements within the allowable range.

4. Field test research

4.1No-load test

In order to verify the results of the theoretical simulation, the flow and pressure of the anchor drilling rig is tested on the test bench firstly. The flow meter is connected at the outlet of the hydraulic pump and the LS feedback valve, this system maintains the idling of the double power heads for testing. The test results are shown in table 2.

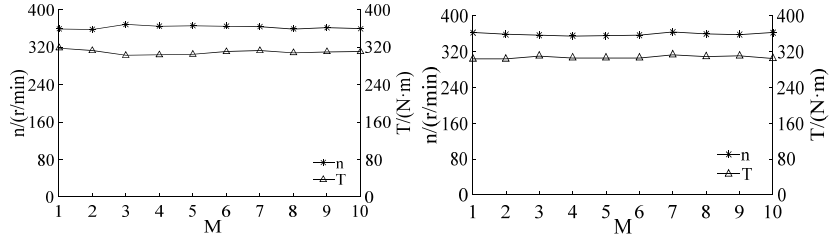
Table 2. Formatting sections, subsections and subsubsections.

project	Outlet flow of hydraulic pump / (L/min)	Hydraulic pump outlet pressure / MPa	LS Feedback pressure /MPa
Middle position	10.8	10.9	5.1
Left rotation	53.3	8.1	3.9
Right rotation	51.7	7.9	4.2
Simultaneously rotation	98.6	8.2	4.3
Simultaneously reverse rotation	99.4	7.9	4.1
Left forward	19.5	8.1	3.5
Right forward	18.3	7.8	3.6
Simultaneously Feeding	40.8	8.0	3.5
Simultaneously Pulling	41.2	8.1	3.4

The results show that when the double power heads are operated individually or simultaneously, the outlet pressure of the variable pump is about 8 MPa. When the hydraulic system is in the middle position, the output flow of the system is 10.8 L/min, and the LS feedback valve pressure is 5.1 MPa, and the system has a certain leakage. When the double power heads are rotated and fed, the system flow and pressure of the single action and simultaneous action have reached the design requirements. There is no significant change in the pressure of the LS feedback valve, indicating that the flow rate of each circuit of the system is not affected by its external load. It is only related to the LS feedback oil circuit.

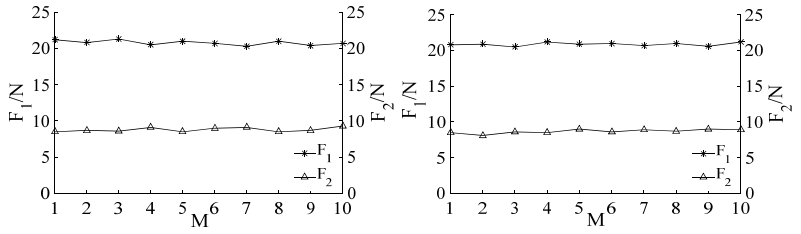
4.2Load test

The two power heads in anchor drilling rig is fixed on the test bench, and the torque meter is connected to carry out the simulated loading test. In order to verify the coordination of the double power head, only the double power heads can be tested separately due to the limitation of the site conditions. When one of the power heads is loaded to the rated condition and the other power head is maintained in the no-load condition, the rated rotation condition and the feed condition obtained are shown in figure 6 and figure 7 respectively.



a) power head 1 b) power head 2

Figure 6. The Rated rotary condition.



a) power head 1 b) power head 2

Figure 7. The Rated feeding condition.

As can be seen from figure 6 and figure 7, under the rated rotation condition, the stable rotational speed of the power head 1 and the power head 2 are 354.1 r/min and 361.3 r/min respectively, the stable output torque are 310.2 N·m and 308.5 N·m respectively. Similarly, under the rated feed condition, the steady feeding force of the power head 1 and the power head 2 are 21.2 kN and 22.1 kN respectively, and the stable pulling force are 8.9 kN and 8.5 kN respectively. The rotational speed and torque of the double power heads meet the design requirements and are basically similar to the simulation results. At the same time, the measurement results of the feeding force and the pulling force also reach the theoretical calculation results.

5. Analysis of field test results

The double power heads in anchor drilling rig was carried out on the ground test. During the test, the double working arm of the anchor drilling rig were in good working condition. The posture adjustment range was wide, the double power heads worked continuously and fluently at the same time, and the efficiency of the whole machine was high. In the final test, four φ30 holes were drilled and the drilling depth was 8 m, the construction time of each drill hole was about 10 minutes, and the construction efficiency was 2 times that of ordinary anchor drilling rig.

6. Conclusions

- The schematic diagram of two power heads in anchor drilling rig's hydraulic system is designed and developed, and its simplified physical simulation model is established.
- The AMESim software is used to simulate the empty load condition and the rated condition of the hydraulic system. The results show that the system flow and pressure of the double power heads can meet the design requirements.
- The anchor drilling rig is tested on a testing bench. The speed and torque of the double power heads can meet the design requirements under the no-load and rated conditions. In the process of field test, the double power heads work reliably and steadily, and do not interfere with each other. the efficiency of the whole machine is high. The research results provide a theoretical basis for the optimization design of the double power heads of the anchor drilling rigs at the same time.

Acknowledgments

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