Characteristics of electromagnetic direct drive hydraulic pump

Electro-hydraulic servo system can give full play to the advantages of electronics and hydraulics. It has the advantages of large thrust or torque, high precision, fast response and good flexibility. Electro-hydraulic servo system was widely used in national defense industry at first, such as aircraft control system, artillery control system, tank artillery stabilizer, missile automatic control system, radar tracking system. Later, with the development of electro-hydraulic servo system, it was gradually extended to civil industrial production, mainly used in various materials testing machine, aircraft simulator, a variety of fatigue testing machine. The original electro-hydraulic servo systems were all valve-controlled electro-hydraulic servo systems, especially the application of electro-hydraulic proportional control technology such as electro-hydraulic proportional relief valve, electro-hydraulic proportional pressure reducing valve, and the development and perfection of proportional components, which promoted the development of electro-hydraulic servo systems. Since the 1990s, various high-performance motors, especially AC servo motors, have been developed successively, and the direct drive concept of "zero-drive" and "near-zero-drive" has been implemented, which makes hydraulic components develop towards integration, high efficiency and low noise. Electromagnetic direct drive hydraulic pump controlled electro-hydraulic servo system has become a hot research topic both at home and abroad. The research and development of new electromagnetic direct drive hydraulic pump also conforms to the idea of "CNC generation" advocated by Professor Zhou Ji, Dean of the Chinese Academy of Engineering.

1.Characteristics of speed control hydraulic system with valve control and pump control

One of the purposes of the electro-hydraulic servo control system is to control the speed of the controlled object, that is to say, speed regulation is one of the core of the electro-hydraulic servo control system. Usually it can be divided into two types: throttle speed regulation and volume speed regulation. The two speed regulation modes are valve-controlled and pump-controlled respectively.

1.1 valve controlled electro hydraulic servo control system

Throttle speed regulation is also called valve-controlled electro-hydraulic servo control system, generally using three-phase AC asynchronous motor drive quantitative pump as the power source of the hydraulic system. Whether the working state of the hydraulic system is no-load or full-load, the speed of the three-phase AC asynchronous motor roughly produces a small fluctuation near the rated speed, so the output flow of the hydraulic pump is basically unchanged, the speed of the controlled object (such as hydraulic cylinder) changes by changing the throttle servo valve.

The opening size is achieved. Valve-controlled hydraulic servo system has the advantages of high precision, high output power and fast response, so valve-controlled hydraulic servo system is widely used in industrial production. But it also has the following obvious shortcomings:
(1) Although the valve-controlled hydraulic servo system has the advantages of high control precision, good linearity and high sensitivity, the contaminated hydraulic oil is easy to cause the wear of the servo valve, thereby affecting the control accuracy of the servo valve and causing

the hydraulic pressure.

80% of the malfunction of the servo system comes from hydraulic oil. Therefore, the valve-controlled hydraulic servo system requires a very high degree of cleanliness of the oil (for example, servo valves often require impurities in the oil should be less than 5 microns). The system needs to be increased.

Filtration technology improves the purity of working oil, so it is necessary to replace hydraulic oil regularly, thus increasing the cost of valve-controlled electro-hydraulic servo system.
(2) In the valve-controlled hydraulic servo system, the pressure and flow of the liquid are usually supplied by the quantitative pump. Therefore, there are relief valves or throttle valves in the system. The throttle valves or relief valves will cause the oil temperature to rise due to the throttle loss.
(3) Because of the complex structure and high price of the servo valve, the price of the servo valve is tens or even hundreds of times that of the ordinary valve. It often needs to be imported, and the supply period is very long.
(4) In the case of power matching, the maximum load pressure provided by the servo valve is only 2/3 of the oil source pressure, and the energy waste of the system is serious.

1.2 direct drive quantitative pump controlled electro-hydraulic servo system
Direct drive quantitative pump-controlled electro-hydraulic servo system is a new mechatro-hydraulic integration technology developed in the last 20 years. The hydraulic system is also known as a fewer-valve electro-hydraulic servo system. Its principle is shown in Fig. 1. The hydraulic system uses a new type of motor, which is different from the AC asynchronous motor, to drive a quantitative hydraulic pump directly to change the flow and pressure of the actuators of the hydraulic system. Use speed motor instead of tradition

The function of servo valve in hydraulic system is its main advantage. Direct drive quantitative pump-controlled electro-hydraulic servo system has the advantages of high resolution, wide speed range, strong oil pollution resistance, high efficiency, easy to realize computer control and so on. For the electro-hydraulic servo system with general technical performance requirements, the functions of the hydraulic system can fully meet the requirements of the traditional electro-hydraulic servo system using servo valves.
The first countries in the world to study direct drive quantitative pump controlled electro-hydraulic servo systems are Japan and the United States. Japan First Electric Company, OPTON Corporation and NAMBU have studied the direct drive quantitative pump-controlled electro-hydraulic servo system for many years, and have achieved some research results. At present, in the United States, Japan, Germany and Sweden and other countries, the direct-drive quantitative pump-controlled hydraulic system has been widely used in many fields, such as aerospace, ships, rolling mills, material testing machines, printing presses, steel continuous casting and other equipment.

2 traditional hydraulic pump driven by AC servo.

2.1 The principle of electro-hydraulic servo system of variable mechanism driven by AC servo motor. Taking the axial piston hydraulic pump with a straight shaft as an example, the main

drive of the pump still uses an AC asynchronous motor, so that the rotational speed of the pump does not change, but by adjusting the inclination angle of the variable swashplate of the pump

To implement variables. The variable displacement piston pump controls the inclination angle gamma of the variable swash plate directly by the AC servo motor through the ball screw nut mechanism, and then realizes the change of the flow rate of the variable displacement piston pump. The hydraulic system

It mainly consists of servo variable hydraulic pump, one-way valve, hydraulic control one-way valve, relief valve, AC asynchronous motor and hydraulic cylinder. The hydraulic pump adopts the direct digital control method, and the traditional analog signal control components such as hydraulic proportional valve or servo valve convert the digital control signal to analog control signal through the digital and analog conversion interface, thus realizing the control mode of proportional valve or servo valve and other control components. The system directly uses digital signals to control the operation of hydraulic components, which has the advantages of simple structure, reliability and convenient control.
2.2 variable speed pump driven by AC servo motor

Variable displacement pump driven by AC servo motor is driven by two AC servo motors, which drive the main shaft and variable mechanism of variable displacement pump directly. The speed and displacement can be adjusted separately, which makes the flow regulation have three ways: constant speed variable displacement, variable speed constant displacement and variable displacement. According to different control modes to meet different working conditions, efficiency requirements, such as setting the minimum speed of the motor higher than the minimum speed of the pump to avoid the low volume efficiency zone; setting the motor to work in the high torque region to solve the problem of low speed torque insufficiency; using variable displacement control when reaching the lower limit set by the motor speed; setting the motor speed. Variable speed control, variable displacement control or compound control are used in the range, and variable displacement control or compound control is used in the system with high dynamic response. The electro-hydraulic servo system of variable pump driven by servo motor can adopt a more suitable control mode, thereby improving the efficiency of the whole hydraulic system. The shortcomings of electro-hydraulic servo system of variable pump driven by AC servo motor make the system more complex and low cost performance. It is only suitable for the occasions where the system response and efficiency are required.

3 typical electromagnetic direct drive integrated hydraulic pump
The traditional motor and hydraulic pump system are all three-stage structure, that is, the motor is connected with the hydraulic pump through the coupling. This connection mode has many shortcomings:
(1) The volume and weight of the hydraulic pump, the core of the motor and the hydraulic pump system, is only about 12% of that of the same power motor. The motor occupies the volume of the whole motor and the hydraulic pump system.Most.
(2) Energy conversion efficiency reduces the motor, hydraulic pump, oil tank, etc. to be completely independent components or components, multiple interconnections and coordination, increasing the complexity of the motor and hydraulic pump system, resulting in energy conversion efficiency.Adverse effects.

(3) Cavitation noise and vibration are easy to occur because the independent hydraulic pump has a closed shell and is independent of the oil tank. The suction port is connected with the oil tank through a pipeline, resulting in the increase of flow resistance and the compression of the space of the oil suction chamber, resulting in local negative pressure in the oil suction passage, causing bubble precipitation, cavitation noise and vibration. The cooling fan in the independent motor also increases the noise of the whole power unit. Independent motors generally use cooling fans for air cooling, which introduces aerodynamic noise and mechanical noise.
(4) Possible leakage exists in the pipeline connecting part between the hydraulic pump and the oil tank and the shaft extension of the hydraulic pump, resulting in potential environmental pollution and loss of hydraulic oil. It is difficult to eliminate the leakage at the dynamic seal of the pump shaft. Even if the initial seal is in good condition, the leakage caused by wear and tear will occur after long-term operation.

In view of these shortcomings, many well-known companies and research institutions at home and abroad have integrated the motor and pump design. In 1980s, the shaft of the hydraulic pump was directly inserted into the spindle of the motor. It is a domestic and foreign manufacturer.

Try to combine motor with hydraulic pump. This type of motor and hydraulic pump system assembled by hydraulic pump and motor has been produced both at home and abroad, including Shanghai High Pressure Oil Pump Plant and Qidong High Pressure Oil Pump Plant. But because the motor needs special orders, the cost has increased, at this time the motor and hydraulic pump system can be called motor oil pump unit, motor, hydraulic pump in the structure of the basic no major changes. With the development of servo motor technology and hydraulic control technology, the motor and hydraulic pump system unit which is designed as one of the motor and pump appeared. The integration of motor and hydraulic pump can be divided into two parts: direct-connected motor and hydraulic pump system and integrated motor and hydraulic pump system (hydraulic motor pump).

4 key technology of electromagnetic direct drive hydraulic pump
Reducing leakage, noise and energy consumption of hydraulic system and improving system efficiency have become one of the main directions and focuses of electro-hydraulic system research. With the improvement of design and the use of energy-saving and high-efficiency hydraulic components, the efficiency of the whole hydraulic system is gradually improved, especially the more energy-saving direct-drive electro-hydraulic servo system, which can improve the efficiency of the electro-hydraulic system by more than 50%. Motor and hydraulic pump system is a highly integrated system of motor and hydraulic pump. The following problems should be solved in design:
4.1 integration of motor and hydraulic pump
At present, the integration of motor and hydraulic pump is mainly composed of two ways: series and parallel. Essentially, there is no essential difference between the series motor and the hydraulic pump system and the ordinary three-stage structure, only removing the coupling, willThe three section structure is simplified into two segment structure. Parallel integrated motor and hydraulic pump system (hydraulic motor pump) has been used.It is the development trend of motor and hydraulic pump system. Due to the structural characteristics of servo motor, how to embed the structure of hydraulic pump into the rotor of the motor is a major problem facing the

hydraulic motor pump. Especially, the rotor center space of ordinary servo motor is limited. If the hydraulic pump is forced into the rotor core, the magnetic density of the yoke of the motor rotor will increase, and the efficiency and power factor of the motor will decrease. Therefore, how to reasonably design the structure of the motor and the hydraulic pump, so that the hydraulic pump can be reasonably embedded in the rotor of the motor to adapt to the structural characteristics of the hydraulic motor pump, hydraulic motor pump is an urgent problem to be solved.

4.2 selection of servo motor

The development of servo motor technology has injected new vitality into the motor and hydraulic pump system, especially the application prospect of AC permanent magnet synchronous motor in motor pump is very good. Almost all the traditional hydraulic pumps are driven by AC asynchronous motors. The starting current is 5-7 times the rated current, the starting time is long (only a few seconds), the efficiency is low, the starting torque is small, and the speed regulation performance is poor. Moreover, AC asynchronous motors have poor traction ability at low speeds, and the allowable rated slip rate is small (often less than 12%), which results in burnout of the motor due to overload. The emergence of special motors such as permanent magnet synchronous motors not only greatly increases the central space of the motor rotor, but also reduces the loss of stator current and stator resistance in principle compared with asynchronous motors, which leads to the total loss and total heating of the motor. At the same time, PMSM also has the advantages of large overload multiple, rapid response, stable operation and compact structure. At present, various high-performance motor topologies, such as fractional slot permanent magnet synchronous motor, disc permanent magnet synchronous motor, transverse magnetic field motor, have been used in various direct drive occasions. It is one of the key problems of hydraulic motor pump to design the suitable topology of motor, select the type of motor, determine the structure parameters and electromagnetic parameters according to the driving needs of different pumps.

4.3 pump distribution scheme

Because of the high integration of the mechanical structure of the electromagnetic direct drive hydraulic pump, the space of the motor pump is limited, the flow channel is narrow and curved, which leads to the increase of suction resistance. How to design the flow channel and design the distribution scheme is very important to the suction performance and efficiency of the motor pump. The volumetric efficiency and service life of the pump. At present, there are two main ways to distribute the flow of hydraulic pump, one is end-face distribution and the other is valve distribution. The valve distribution structure avoids the leakage and wear of the friction pair of the valve plate, and the other is shaft holding in the shaft distribution structure. However, when the pump speed is high, the response lag of the valve core has a greater impact on the suction and pressure out of the hydraulic pump.

5 development trend of electromagnetic direct drive hydraulic pump

Direct drive pump-controlled electro-hydraulic servo system is composed of quantitative pump or variable pump, variable speed motor and actuating hydraulic components. Compared with valve-controlled electro-hydraulic servo system, pump-controlled hydraulic servo system has the advantages of simple system structure, low calorific value, high efficiency and insensitivity to oil performance, but it has no throttling loss. There are also the following disadvantages:

(1) The system has the disadvantages of complex structure, large inertia and poor stability of motor pump, so the control speed of the system is not as fast as that of valve control system.

(2) the efficiency of the motor varies with load. When the load is small, the efficiency of the motor is low and the waste of energy is serious.
(3) Because the servo motor speed range is limited, and the variable displacement pump skew angle range is also limited, so the hydraulic pump flow range is limited, the system debugging range is limited;
(4) The AC permanent magnet servo motor of electromagnetic direct drive hydraulic pump still has high price at present, especially the high-power motor and its driver mainly depend on import.
(5) the electromagnetic direct drive hydraulic pump is not standardized and lacks national, industry and enterprise standards. Therefore, the choice of users is greatly restricted, resulting in the difficulty of popularization and application of this new type of pump. Electromagnetic direct-drive hydraulic pump is superior to transmission hydraulic system and valve-controlled electro-hydraulic servo system in energy-saving and noise reduction, improving the performance of the whole hydraulic system, improving efficiency and stability. With the development of servo motor control technology and motor pump technology, its application field will continue to expand.

The integration of motor and hydraulic pump, the development of servo motor technology, the research of electro-hydraulic servo control technology and the solution of flow distribution scheme are the key problems that restrict the development of direct drive pump-controlled electro-hydraulic servo system, especially the development of serialized and standardized new special servo motor and frequency converter to reduce its cost and improve its low speed performance. It is of great significance to improve the performance of direct drive pump controlled electro-hydraulic servo system.