Improvement of Operation Stability of Hydraulic Cylinder

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Abstract: In the speed control loop of hydraulic system, the unstable speed of hydraulic cylinder and hydraulic impact often occur, which makes the hydraulic machinery unable to work normally. In this paper, the causes of unstable motion of hydraulic cylinder are analysed from the following aspects: the load of throttle speed control loop varies greatly, the pressure difference between front and back of speed control valve is too small, and the hydraulic impact occurs when the speed is changed. Specific improvement methods are put forward.

1. Introduction
Speed regulation is an important part of hydraulic system. the speed of the actuator is unstable, hydraulic machinery cannot work normally, seriously affecting the quality and efficiency of work. Speed regulation is mainly by the flow control valve to change the throttle size, and then change the throttle flow through the valve to achieve speed control of the hydraulic cylinder. In various speed control loops, hydraulic cylinder speed instability, hydraulic impact and other phenomena often occur. Therefore, it is an important task to analyze the cause of failure and propose improvement measures.

2. Improvement of speed regulating circuit for oil inlet and throttle
As shown in Fig. 1 (a), the throttling speed control circuit with throttle valve is designed according to the small change of hydraulic cylinder load. In practical application, the external load of the hydraulic cylinder changes greatly, resulting in unstable speed of the hydraulic cylinder. The reason for the unstable speed is that the throttle valve's flow rate is affected by the hydraulic pressure difference before and after the throttle valve when it works under certain conditions. When the external load changes, the hydraulic cylinder speed cannot keep stable with the hydraulic pressure difference before and after the throttle valve. In order to keep the flow through the throttle valve from changing with the external load, it is necessary to compensate the pressure difference between the front and back of the throttle valve, so that the difference between the front and back of the throttle valve can be approximately constant when the load changes.

As shown in Figure 1 (b), it is the simplest solution to replace throttle valve with speed control valve 6. If there is no suitable speed control valve, the following methods can be used to solve it.
As shown in Figure 1 (c), a pressure relief valve 7 is installed in front of the throttle valve and the relief port of the pressure relief valve is connected to the pipeline between the hydraulic cylinder and the throttle valve. The following results can be achieved: the pressure reducing valve 7 can keep the pressure behind the valve as a stable value. When the external load of the hydraulic cylinder increases, the pressure of the rod-less chamber of the hydraulic cylinder increases, the pressure of the relief valve outlet increases, and the pressure behind the relief valve increases, so the pressure difference between the front and back of the throttle valve is basically unchanged. When the load of hydraulic cylinder decreases, the pressure of rod-less chamber decreases, the pressure of relief valve outlet decreases, the pressure behind the relief valve decreases, and the pressure difference before and after the throttle valve remains basically unchanged. Therefore, when the external load changes, the throttle valve can still obtain a stable flow, so that the hydraulic cylinder speed is stable.

As shown in Figure 1 (d), a remote pressure regulating valve is installed on the remote control port of relief valve 2 and its return port is connected to the pipeline between the throttle valve and the hydraulic cylinder, so that the regulating pressure of pressure regulating valve 8 is lower than the regulating pressure of the relief valve. When the external load of hydraulic cylinder increases, the pressure of rod-less chamber increases, and the outlet pressure of pressure regulating valve 8 increases, which results in the increase of the front pressure of pressure regulating valve 8 and the pressure of relief valve 2 control port. Therefore, the front pressure of relief valve 2 increases, and the pressure difference between the front and back of throttle valve is basically unchanged. Conversely, when the hydraulic cylinder load is reduced, the pressure difference between the front and rear of the throttle valve can still be controlled basically unchanged. The pressure difference between the front and rear throttle valves is constant, and the flow rate is constant, so that the movement speed of the hydraulic cylinder is basically unchanged.

3. How to improve the pressure difference between the front and rear of speed control valve

Figure 2 shows the working principle of the speed control valve. The main principle is to use a variable hydraulic resistance (constant differential pressure reducing valve) which can be automatically adjusted to ensure that the pressure difference between the front and back of a fixed hydraulic resistance (throttle valve connected in series behind the pressure reducing valve) is basically unchanged, so that the flow through the speed control valve can be kept constant when the pressure...
difference changes before and after the speed control valve. As a result, the speed of the hydraulic cylinder can maintain uniform speed under the condition of external load changes.

Figure 2 shows that the pressure difference between the front and back of the speed regulating valve should be higher than that between the front and back of the throttle valve for speed regulating because the two hydraulic resistances are in series. Generally, the pressure difference between the front and back of the speed regulating valve should be kept in the range of 0.5~0.8 MPa. If the pressure difference is less than 0.5 MPa, the pressure reducing valve cannot work properly and cannot play the role of pressure compensation. Obviously the pressure difference between the front and back of the throttle valve cannot be constant, so the flow through the speed valve changes with the external load, the speed of the hydraulic cylinder is unstable.

Figure 3 (a) shows that the hydraulic oil in the loop enters the rod-less chamber of the hydraulic cylinder through a one-way valve, lifts the load, and the oil in the rod chamber passes through the tank. Hydraulic cylinder descends by self-weight, the oil in the rod less chamber returns to the tank through the speed regulating valve, which is equivalent to the speed regulating valve return oil throttling speed regulation, so the hydraulic cylinder descending speed should be stable. But the hydraulic cylinder of this circuit is unstable when it drops.

When the hydraulic cylinder descends, the hydraulic pump has unloaded. The pressure in the rod-less chamber of the hydraulic cylinder is only determined by the weight and has nothing to do with the output pressure of the hydraulic pump. Therefore, the oil pressure in the rod less cavity depends on the load and piston area.
The pressure difference between the front and rear of the speed control valve must reach 0.5~0.8MPa, and the differential pressure reducing valve can work normally. The reason why the above loop speed is unstable is that the pressure difference between the front and rear of the speed regulating valve is low. Reducing the area of the piston of the hydraulic cylinder can increase the pressure difference between the front and rear of the speed control valve, but this is difficult. As shown in Fig. 3(b), the two-position three-way valve is changed to a two-position four-way valve, and when the hydraulic cylinder is lowered, the rod chamber is input with pressure oil. The system pressure is set by the relief valve, and part of the pressure oil output from the hydraulic pump enters the hydraulic cylinder, and a part of the pressurized oil overflows from the overflow valve to the oil tank. The down speed of the hydraulic cylinder is set by the relief valve. The adjustment pressure of the relief valve is increased, and the pressure difference between the front and the rear of the speed control valve is increased to ensure the pressure difference of the normal operation of the speed control valve. The speed of the hydraulic cylinder does not change with the load, and the hydraulic cylinder can be stably lowered.

4. Improvement of hydraulic shock when speed is switched

Figure 4 (a) shows that when the hydraulic cylinder is working and feeding, the hydraulic cylinder is converted by the speed regulating valve 4 and 5 through the reversing valve 6, resulting in a greater hydraulic impact.

The components are tested and the system is debugged. The components are working normally and there is no excess gas in the system.

Because the impact occurs when the hydraulic cylinder is switched from one speed to another, it can be analyzed that the fault is caused by the improper use of the speed control valve, that is, by the jump phenomenon of the pressure compensation device of the speed control valve when the speed is switched.

When the speed regulating valve is in normal operation, the constant differential pressure reducing valve connected in series with the throttle valve automatically adjusts to a proper opening, so that the pressure difference between the two ends of the throttle valve is a fixed value. In the circuit shown in Fig. 4 (a), no working oil passes through the speed valve before the speed change, and the pressure reducing valve opens most under the action of the spool spring. At this point, the speed change starts with the reversing valve 6, and the pressure oil flows rapidly into the speed regulating valve, which makes the pressure instantaneously increase behind the pressure reducing valve, and the pressure
difference between the two ends of the throttle valve is very large, and the flow through the valve is also very large, so that the hydraulic cylinder moves rapidly. In an instant, under the action of the pressure behind the valve, the opening of the valve core reaches the minimum, and the flow rate through the valve also drops to the minimum. At this time, the hydraulic cylinder slows down rapidly. This process is repeated many times before the flow reaches a stable value. The hydraulic impact is generated when the hydraulic cylinder changes speed.

The fault can be eliminated by changing the loop into the form shown in Figure 4 (b) or figure 4 (c).

![Diagram](image)

(a) before improvement  (b) improvement 1  (c) improvement 2

Fig. 4 loop for speed switching

Fig. 4 (b) shows that the timing valve is in series. At the diagram position, the pressure oil is returned to the tank through the governor valve 4, 5 and the reversing valve 6. After the reversing valve 6 and 10 are energized, the left position works, the speed regulating valve 4 starts to work, and the speed of the hydraulic cylinder is regulated by the speed regulating valve 4. When the reversing valve 10 is not energized and the reversing valve 6 is energized, the governing valve 4 and 5 are all in working state. Obviously, in the hydraulic cylinder speed change process, both speed control valves always have pressure oil through, thus avoiding the above-mentioned failure. In such a speed control loop, the flow section of speed control valve 5 should be adjusted less than speed control valve 4, otherwise the speed cannot be changed.

Fig. 4 (c) shows that the timing valve 4 and 5 are connected in parallel. In the diagram position, both speed control valves have pressure oil through, when the reversing valve 6 and 10 are connected, speed control valve 4 works; when the reversing valve 6 is connected, the reversing valve 10 is cut off, speed control valve 5 works. It can be seen that the speed control valve also has pressure oil passing at every moment of speed change, so as to avoid the above-mentioned failure.

5. Conclusions

Through theoretical analysis and experimental verification, in order to ensure the steady speed of hydraulic cylinder, the pressure difference before and after the throttle valve should be kept constant in the speed control loop using the throttle valve. In the speed control loop of the speed control valve, the pressure difference between the front and back of the speed control valve must be above 0.5~0.8 MPa, so that the speed control valve can work stably. In the speed change circuit, the sudden change of pressure should be avoided.

There are many reasons for the unstable speed of hydraulic cylinder. As long as we keep exploring in practice, we can find effective solutions.
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