Analysis of working characteristics of throttle speed regulating valve

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Abstract. In this paper, combined with the working requirements of throttling speed regulation in the circuit, the structure principle and working characteristics of speed control valve in flow control valve are analyzed, the speed regulating performance and characteristics of speed regulating valve in hydraulic system are expounded. It is pointed out that the relationship between speed and load of speed regulating valve is rigid in the process of speed regulating of hydraulic system, that is to say, the speed regulating valve is suitable to be used in the case of large load variation, high speed stability requirements of the occasion.

Key word: Speed regulating valve; Throttle speed regulation; Flow characteristics; Speed stability.

1. Introduction
Speed control valve belongs to flow control valve, it is composed of throttle valve and constant pressure reducing valve, in the flow control regulation, the main way is to adjust the flow area of throttle valve, and then adjust the liquid resistance and output flow. So as to control the movement speed of the actuator, Velocity is equal to flow divided by flow area, Namely: \( v = \frac{q}{A} \). This paper will focus on the analysis of the structural characteristics and working characteristics of the speed control valve.

2. Structure and working principle of speed regulating valve
Speed control valve is mainly composed of throttle valve and constant differential pressure reducing valve, as shown in Figure 1. The valve mainly has valve body, valve core of constant differential pressure reducing valve, spring, throttle valve core and adjusting hand wheel. During flow control, by adjusting the handwheel, \( Move \) to change the position of throttle valve spool, and then control the size of the orifice of the throttle valve, so as to control the flow output, and because of the original hydraulic cylinder, once installed, Its effective oil loading area can not be changed, adopt \( v = \frac{q}{A} \). Finally, the movement speed of the actuator hydraulic cylinder is adjusted.
3. Analysis of working characteristics of throttle speed regulating valve

It can be seen from the throttle speed regulating circuit at the inlet of speed regulating valve in Figure 2, the movement speed of the hydraulic cylinder is controlled by the throttle valve in the speed regulating valve, the calculation formula of oil flow through throttle valve is:

\[ q_1 = C A_f \Delta p \]

Where: \( q_1 \) represents the flow of throttle valve;
C from the character of the pore, size and liquid properties; among, Slender hole \( C = d^2/32\mu l \);
Thin walled and short holes \( C = c_q \sqrt{2/\rho} \);
\( A_f \) represents the flow area of the throttle valve;
\( \Delta p \) represents the pressure difference between the inlet and outlet ends of the throttle valve;
m Index determined by the ratio of length to diameter of the hole; Slender hole m=1; Thin wall hole m=0.5; Short hole 0.5<m<1.

Based on formula (1-1) formula, \( \Delta p \) is the pressure difference between the inlet and outlet ends of the throttle valve in the speed control valve. It is shown in Figure 2, \( \Delta p = p_2 - p_3 \), \( p_3 \) is related to external load, At the same time, \( p_2 \) is set by constant pressure reducing valve, However, the pressure established by the external load will be fed back to the spool of the differential pressure reducing valve through the feedback channel a, change the valve port position of constant differential pressure reducing valve, And change \( p_2 \).

But figure 2 shows the throttle and speed regulating circuit at the inlet of the speed regulating valve, the power unit installed in this circuit is a constant displacement pump, therefore, the valve port of direct acting relief valve in this circuit is normally open, Suppose that the setting pressure of direct acting relief valve is \( p_1 \), Then the pressure at the inlet of the speed regulating valve and the pressure at the outlet of the quantitative pump are \( p_1 \); Since the oil entering the speed regulating valve first passes through the constant differential pressure reducing valve, so in the role of constant pressure reducing valve, The pressure of the oil flowing out of the constant differential pressure reducing valve is reduced to \( p_2 \), \( p_2 \) through the channels in the constant differential pressure reducing valve, they reach cavity \( A_c \) and cavity \( A_b \) respectively, Throttle valve outlet pressure \( p_3 \) determined by external load, \( p_3 \) acts on the cavity of \( A_a \) through the feedback channel a inside the valve body; is required in the design of constant differential pressure reducing valve in speed regulating valve \( A_a = A_b + A_c \); When the valve core of constant differential pressure reducing valve is in spring \( F_t \), oil pressure \( p_3 \) and \( p_2 \) in a certain equilibrium position(the friction force and hydrodynamic force are ignored), then the force balance equation of the valve core is expressed as:

\[
p_2 A_c + p_2 A_b = p_3 A_a + F_t \tag{2}
\]

Because:

\[
A_a = A_b + A_c \tag{3}
\]

So formula (1-2) can be obtained:

\[
p_2 (A_c + A_b) = p_3 A_a + F_t
p_2 A_a = p_3 A_a + F_t
p_2 A_a - p_3 A_a = F_t
\]

The arrangement can be obtained:

\[
p_2 - p_3 = \Delta p = \frac{F_t}{A_a} \tag{4}
\]

In formula (1-4), \( p_2 \) is the inlet of throttle valve in speed regulating valve; \( p_3 \) is the outlet of throttle valve in speed regulating valve; \( F_t \) is the internal spring force of constant pressure reducing valve; \( A_a \) is the effective area of the right chamber in the constant differential pressure reducing valve.

It can be seen from formula (1-4), Because \( F_t \) is the internal spring force of constant pressure reducing valve, \( A_a \) is the effective area of the right cavity in the constant differential pressure reducing valve, the above two parameters are fixed, therefore, the inlet and outlet pressure of throttle valve in speed control valve is constant.

According to the force balance formula of the hydraulic cylinder when it works stably, available:

\[
p_3 A_4 - p_5 A_5 = F \tag{5}
\]

In formula (1-5), because of the rod cavity directly connected to the oil tank, therefore \( p_5 \approx 0 \), the formula can be simplified as:

\[
p_3 A_4 = F
\]

Namely
Adjusting handwheel

Orifice

$P_3$ pressure increases

$P_2$ pressure also increases

$P_1$, $P_2$, $P_3$ pressures

Fig. 3 outlet $p_3$ of speed control valve increases with load

Where, $F$ is the external load force;
$A_4$ is the effective working area of hydraulic cylinder rodless cavity.

As shown in Figure 3, When the external load $F$ increases, $p_3$ increase. When $p_3$ increased, $p_3$ acts on the cavity of $A_a$ through the feedback channel a inside the valve body, So the pressure in the $A_a$ cavity increases. At this time, the force balance equation of constant differential pressure reducing valve spool (1-2), Adjust to $p_2A_c + p_2A_b < p_3A_a + F_t$, Then the valve core of the constant differential pressure reducing valve loses balance and moves to the left, Therefore, the valve port of constant differential pressure reducing valve increases, Reduction of liquid resistance, The pressure reducing effect of the pressure reducing valve is also reduced, The $p_2$ of the outlet of the constant differential pressure reducing valve and the inlet of the throttle valve increases accordingly, Until the constant differential pressure reducing valve spool is balanced in the new position. Therefore, when the outlet $p_3$ of the throttle valve which regulates the flow in the speed regulating valve increases, The inlet $p_2$ of throttle valve also increases, Therefore, the pressure difference between the inlet and outlet ends of the throttle valve in the governor valve $\Delta p = p_2 - p_3$ remains basically unchanged.

In the same way, as shown in Figure 4, When the external load $F$ is reduced, According to formula (1-6), $p_3$ decreases. When $p_3$ decreases, $p_3$ acts on the cavity of $A_a$ through the feedback channel a inside the valve body, So the pressure in the $A_a$ cavity decreases. At this time, the force balance equation of constant differential pressure reducing valve spool (1-2), Adjust to $p_2A_c + p_2A_b > p_3A_a + F_t$, Then the valve core of constant differential pressure reducing valve is out of balance, Now it moves to the right, Therefore, the pressure reducing port of the constant differential pressure reducing valve is reduced, The constant differential pressure reducing valve begins to reduce pressure, $p_2$ decreased, Until the constant differential pressure reducing valve spool is balanced in the new position. Therefore, when the outlet $p_3$ of the throttle valve regulating the flow in the speed regulating valve is reduced, The inlet $p_2$ of throttle valve also decreases, Therefore, the pressure difference between the inlet and outlet ends of the throttle valve in the speed control valve $\Delta p = p_2 - p_3$ remains unchanged again.
It can be seen from this, because the constant difference pressure reducing valve in the speed regulating valve can change with the external load force, Automatic adjustment of hydraulic resistance, Therefore, the pressure difference between the inlet and outlet ends of the throttle valve in the speed regulating valve is not changed, thus the stability of flow control is realized.

4. Conclusion
From the above analysis, we can get a clear conclusion, When the speed control valve controls the flow in the loop, The movement speed of the actuator hydraulic cylinder will not change with the change of the external load, The reason is that the speed control valve is based on the throttling principle of throttle valve, A set of pressure compensation device is added to the internal structure of the valve, The phenomenon of large pressure loss after throttling is improved, The pressure of the fluid after throttling is basically equal to that before throttling, And reduce the heat of the fluid, Therefore, the speed control valve is suitable for large load variation, And the speed is required to be stable.

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