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Research on pressure drop method of hydraulic automatic transmission hydraulic control system

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Research on pressure drop method of hydraulic automatic transmission hydraulic control system

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Abstract. The dynamic model of the hydraulic control system of the shift clutch is established through the flow equation of the valve port, the flow continuity equation and the balance equation of the valve core force, Simulate the variation of oil pressure in the inlet of clutch cylinder under different duty cycles. The fluctuation of the oil pressure at the inlet of the clutch hydraulic cylinder was simulated with different duty ratio reduction modes of the shift solenoid valve. Find a way that the duty cycle of oil pressure fluctuation decreased smallest.

Keywords: Shifting of hydraulic mechanical automatic transmission; Pressure regulating valve; Clutch hydraulic cylinder; Oil pressure fluctuation.

1. Introduction

The hydraulic control system plays an important role in AT automatic transmission [1]. The essence of the shift process is the process of separating and combining the clutch [2]. Usually, the separation process of the separation clutch is controlled by open loop. Due to the existence of damping in clutch hydraulic control system, the inlet of clutch hydraulic cylinder fluctuates with the decrease of duty cycle of shift solenoid valve. The fluctuation of hydraulic pressure causes the fluctuation of the torque the clutch transmitted, which has a bad effect on the smoothness of gear shifting. Find out a way that the fluctuation of hydraulic cylinder' pressure is minimum [3].

2. Structure and working principle of hydraulic control system for shift solenoid valve

The principle diagram of the hydraulic control system of Allison3500R automatic transmission is shown in Fig 1, mainly made up by shift solenoid valve 1, throttle valve 3, throttle valve 10, accumulator (valve body 4, reset spring 5, piston 6), clutch hydraulic cylinder (piston 7, clutch friction plate 8, spring 9), clutch pressure regulating valve (shift electromagnetic valve control chamber 2, The reset spring 11, the valve core 12 and the valve body 13.



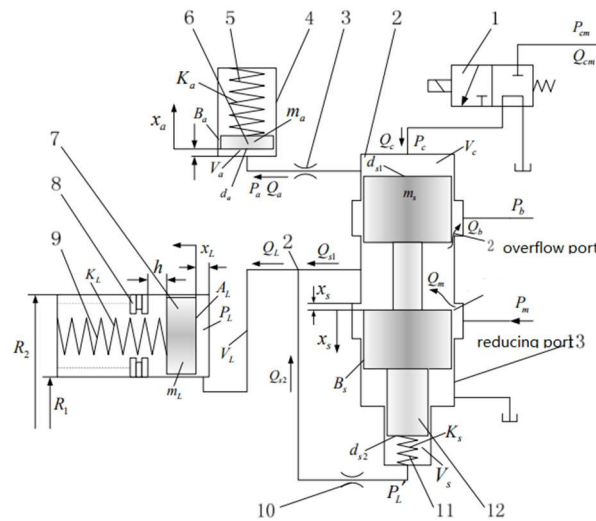


Fig. 1 Schematic diagram of hydraulic control system for Allison3500R type automatic transmission

Shift solenoid valve structure as shown in Fig 2. The control chamber pressure of the pressure regulating valve is determined by the duty ratio of the shifting electromagnetic valve. The valve control chamber is connected with a spring accumulator to eliminate the fluctuation of the oil pressure in the control chamber [4]. When the pressure of the pressure control valve is small, the valve core is at the top of the valve body under the action of spring force. The piston of the clutch cylinder is at the right end of the cylinder body under the action of the spring. When the solenoid valve is electrified, the control chamber of the pressure regulating valve rises, after reaching a certain value, the valve core overcomes the spring force to move down. The opening of the overflow opening gradually decreases until it is closed. After closing, the pressure relief opening is opened, and the clutch hydraulic cylinder establishes pressure. The opening of the overflow opening gradually decreases until it is closed. After closing, the decompression port is opened, and the clutch hydraulic cylinder establishes pressure. Feedback to the sensitive chamber of the regulating valve the pressure is very small, the valve core continues to move down. The opening of the reducing outlet continues to increase, the hydraulic cylinder is quickly filled with oil, and the piston moves to the left fast to the active piece of the clutch friction plate, reducing the duty cycle of the solenoid valve, the pressure of the pressure chamber of the pressure regulating valve decreases, the valve core moves upward, and the opening of the decompression port decreases. The hydraulic pressure of the inlet of the clutch cylinder decreases, and the piston speed decreases. The clutch driving plate moves slowly under the driving of the piston of the hydraulic cylinder and contacts with the driven disc and transmits torque. After full contact, the duty ratio of the solenoid valve increases to the maximum. The pressure of the inlet of the hydraulic cylinder increases rapidly, and the torque transmission capability between the clutch driving plate and the driven plate increases, feedback to the sensitive cavity of the pressure regulating valve by the damping hole 10. Under the action of the valve sensitive cavity, the valve core moves upwards and turn down the reducing outlet. Clutch hydraulic cylinder inlet pressure stabilized to a specific value, reached the stable state. This is the pressing process of the clutch.

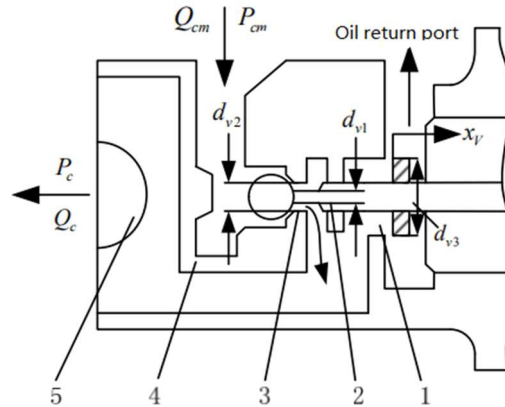


Fig. 2 The structure of shift solenoid valve

3. Mathematical model of pressure control system of shift clutch

Using valve port flow equation, flow continuity equation and valve core force balance equation to establish the nonlinear mathematical model and describe the dynamic characteristics of the hydraulic control system of the shift clutch[5].

3.1. Mathematical model of shift solenoid valve

As shown in Fig. 2, the inlet port of the shift solenoid valve is a ring fixed throttle, and the outlet port is a variable throttling port. The overflow area is proportional to the displacement of the valve core.

The flow rate of inlet valve are as follows:

$$Q_{in} = C_{dv1} A_{v1} \sqrt{\frac{2}{\rho} (P_{cm} - P_c)} \quad (1)$$

The flow from the outlet of the valve are as follows:

$$Q_{out} = C_{dv2} A_{v2} \sqrt{\frac{2}{\rho} P_c} \quad (2)$$

The flow of the control cavity of the flow pressure regulating valve is as follows:

$$Q_c = Q_{in} - Q_{out} = C_{dv1} A_{v1} \sqrt{\frac{2}{\rho} (P_{cm} - P_c)} - C_{dv2} \pi d_{v3} \sqrt{\frac{2}{\rho} P_c} \quad (3)$$

The flow continuity equation of pressure control valve control chamber is as follows:

$$Q_c - Q_a = A_{s1} \frac{d_{xs}}{dt} + \frac{V_c}{\beta_e} \frac{dP_c}{dt} \quad (4)$$

3.2. Mathematical model of pressure regulating valve

The flow through the overflow outlet and the pressure outlet is respectively:

$$Q_m = C_{ds} A_{ds1} \sqrt{\frac{2}{\rho} (P_m - P_L)} \quad Q_b = 0 \quad (x_s \geq 0) \quad (5)$$

$$Q_b = C_{ds} A_{ds2} \sqrt{\frac{2}{\rho} (P_L - P_b)} \quad Q_m = 0 \quad (x_s \leq 0) \quad (6)$$

When the piston of the clutch hydraulic cylinder is not pressed with the clutch active disk, the output flow of the pressure regulating valve is mainly used for the rapid movement of the clutch cylinder, and the flow continuity equation is as follows:

$$Q_{s1} - Q_{s2} - C_{ec} P_L = A_L \frac{dx_L}{dt} + \frac{V_L}{\beta_e} \frac{dP_L}{dt} \quad (7)$$

When the driving disc and driven disc of the clutch are pressed, the hydraulic cylinder of the clutch is not moving at the maximum displacement, and the output flow of the pressure regulating valve is mainly used to provide the pressure produced between the clutch main and the driven disc. The flow continuity equation at this time is as follows:

$$Q_{s1} - Q_{s2} - C_{ec} P_L = \frac{V_L}{\beta_e} \frac{dP_L}{dt} \quad (8)$$

The flow continuity equation of pressure sensitive valve is:

$$A_{s2} \frac{dx_s}{dt} + Q_{s2} = \frac{V_s}{\beta_e} \frac{dP'_L}{dt} \quad (9)$$

The flow over the damped hole 2 is:

$$Q_{s2} = C_{d2} A_{d2} \sqrt{\frac{2}{\rho} (P_L - P'_L)} \quad (10)$$

Force balance equation of the valve core of pressure regulating valve is as follows:

$$P_c A_{s1} - P'_L A_{s2} = m_s \frac{d^2 x_s}{dt^2} + B_s \frac{dx_s}{dt} + k_s (x_s + x_{s0}) + F_s + F_t \quad (11)$$

3.3. Mathematical model of clutch hydraulic cylinder

The force balance equation of the piston of a clutch hydraulic cylinder is as follows:

$$P_L A_L = m_L \frac{d^2 x_L}{dt^2} + B_L \frac{dx_L}{dt} + k_L (x_L + x_{L0}) \quad (12)$$

4. Dynamic characteristic simulation of shift clutch pressure control system

According to formula (1) - (12), building the dynamic model of shift clutch hydraulic control system, carry out Simulink simulation for the model. The model block diagram is shown in Fig 3. The system input contains pressure P_{cm} supplied for solenoid valve, main oil pressure P_m and solenoid valve control signal duty cycle τ . Output is clutch hydraulic cylinder inlet oil pressure P_L . The simulation results are shown in Fig 4.

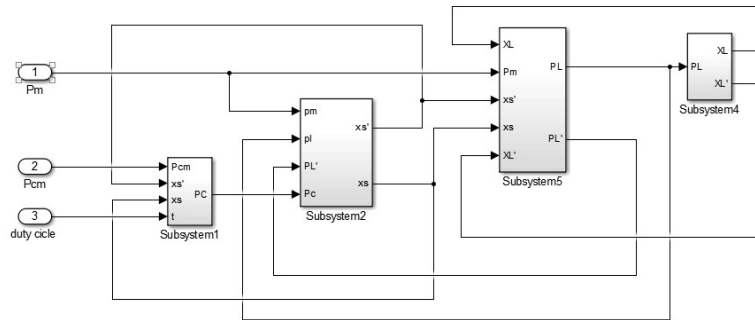


Fig 3. Simulink simulation block diagram of shift clutch pressure control system

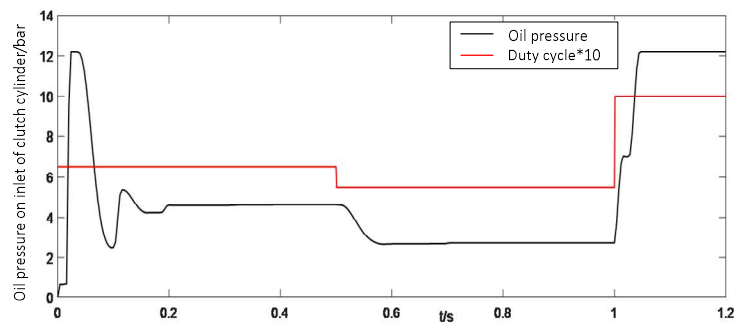


Fig 4. Oil pressure P_L change of clutch hydraulic cylinder

The hydraulic control system of the shifting clutch of the hydraulic mechanical automatic transmission is simulated under the changing duty cycle of the shifting solenoid valve. The result is shown in Fig 4. From the diagram, the duty cycle of the shift solenoid valve is 0.65, 0.55 and 1 respectively. Under different duty cycle signals, the hydraulic pressure of the inlet of the clutch cylinder becomes smaller and then becomes larger.

From the results of Fig 4, it can be seen that because of the non-negligible damping of the pressure regulating valve and the clutch hydraulic cylinder in the hydraulic control system of the shift clutch, the hydraulic pressure at the inlet of the clutch hydraulic cylinder varies with the duty ratio of the shift solenoid valve, but exists certain fluctuations. When the oil pressure fluctuation is large, the transmission torque of the clutch / brake will be affected, and then the shift smoothness will be affected. The duty drop of several typical shifting electromagnetic valves is analyzed, and the fluctuation of oil pressure is observed.

(1) The shift solenoid valve is directly reduced to 30% duty cycle from the maximum duty ratio. The downward trend of duty ratio is shown in Fig 5. The hydraulic pressure of the inlet port of the shift clutch cylinder is shown in Fig 6.

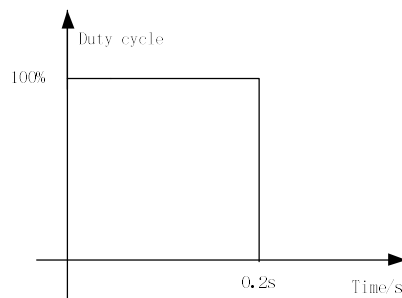


Fig 5. Duty cycle change of shift solenoid valve

(2) As shown in Fig 6, the oil pressure at the inlet of the clutch hydraulic cylinder decreases with the decrease of duty cycle of the shift solenoid valve. There is a certain fluctuation in the oil pressure before reaching the stable value. The fluctuation is about 1.2bar. The speed and fluctuation value of oil pressure decrease are not good for shifting smoothness.

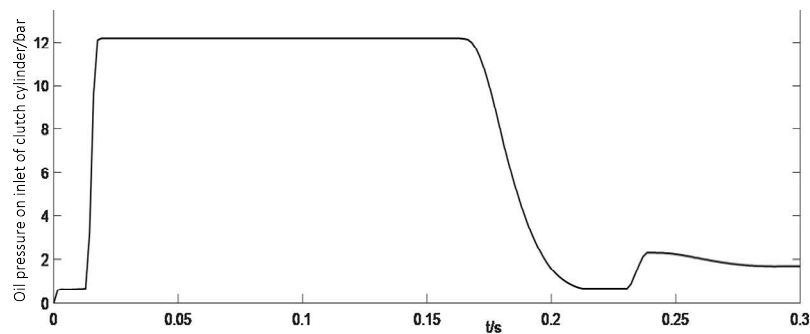


Fig 6. Oil pressure variation diagram of inlet port of shift clutch hydraulic cylinder

(3) Shift solenoid valve by the maximum duty cycle according to a certain slope down to 30% duty cycle. The downward trend of duty ratio is shown in Fig 7. The hydraulic pressure of the inlet port of the shift clutch cylinder is shown in Fig 8.

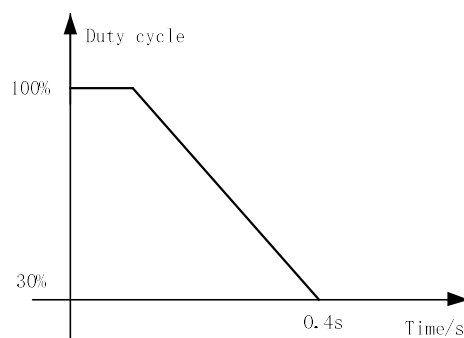


Fig 7. Duty cycle change of shift solenoid valve

As shown in Fig 8, when the duty ratio of the shift solenoid valve decreases at a certain slope, the oil pressure at the inlet of the clutch hydraulic cylinder also decreases at a certain slope. But in the process of decline, the oil has a fluctuation of about 2bar. The fluctuation of oil affects the transmission torque of clutch, which is not conducive to shifting smoothness.

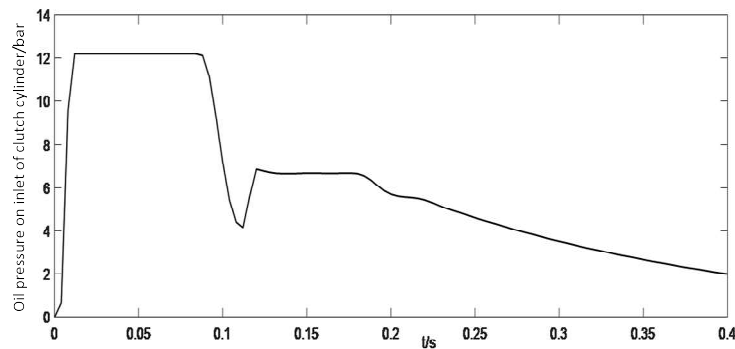


Fig 8. Oil pressure variation diagram of inlet port of shift clutch hydraulic cylinder

(4) The shift solenoid valve is directly reduced to 80% duty cycle from the maximum duty cycle. After a interval, it decreases to a 30% duty cycle according to a certain slope. The downward trend of duty ratio is shown in Fig 9. The hydraulic pressure of the inlet port of the shift clutch cylinder is shown in Fig 10.

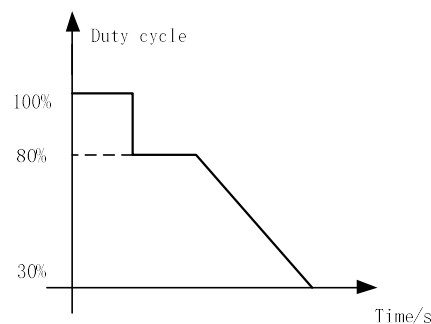


Fig 9. Duty cycle change of shift solenoid valve

As shown in Fig10, when the duty cycle of the shift solenoid valve decreases as shown in Figure 9, the oil pressure at the inlet of the clutch cylinder slowly decreases. The duty cycle of shift solenoid valve has less fluctuation of oil pressure at the inlet of clutch in this way than in the previous several modes of oil pressure drop. It is good for shifting smoothness.

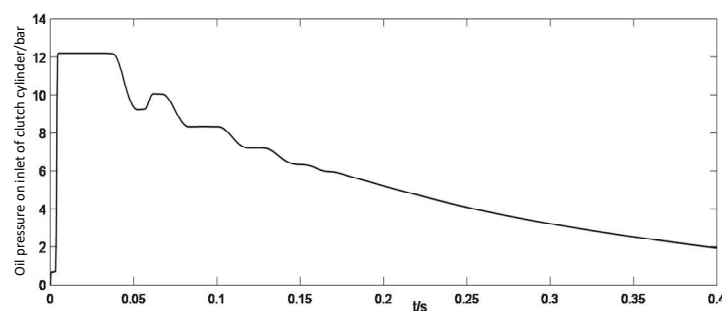


Fig 10. Oil pressure variation diagram of inlet port of shift clutch hydraulic cylinder

5. Conclusion

Valve duty cycle that the smaller the reduction amplitude of shift solenoid valve duty cycle, the smaller the fluctuation of oil. When the shift duty ratio of the solenoid valve is reduced as shown in Figure 9, the oil pressure fluctuation is minimal.

Acknowledgments

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