IOP Conf. Series: Materials Science and Engineering **735** (2020) 012006 doi:10.1088/1757-899X/735/1/012006

Characteristic Analysis of Adjustable Speed Equilibrium Loop of an Electric Proportional Three-way Valve

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Abstract: Based on the research of the existing balance valve and valve control balance loop at home and abroad, this paper constructs a quantitative pump adjustable speed balance loop based on proportional three-way valve, on the basis of analyzing the working principle of the circuit. The speed regulation of load motion in the loop is carried out by using the quantitative pump, and the working principle of the circuit is briefly analyzed. Through the analysis of theory and principle, the simulation analysis model of the equilibrium loop and important components is constructed by using AMESim software. Combined with theoretical analysis, the velocity influencing factors of the circuit are put forward, and then the velocity and pressure curves of the model loop under various parameters are obtained by adjusting some parameters which affect the characteristics of the system, which provides some guiding significance for the study of the balance loop of the single-acting cylinder and the optimization design of the next step.

1. Introduction

Balance circuit is an important part of fluid research field to make the system complete its task. Its main function is not to transfer power, but to satisfy some specific functions to ensure the smooth operation of the executing elements. Hydraulic system balance circuit can be used in a variety of applications, mainly used to maintain the vertical position of the hydraulic cylinder and its connected components do not fall due to self-weight [1]. The hydrodynamic action forms of different spools and orifices are different, and the influence on the loop characteristics is also different [2].

The study of system stability with balancing valves is generally complex. Variable pump or quantitative pump can be used to adjust the velocity of load in the system. Variable pump can achieve accurate flow control, but the cost is relatively high [3].

2. Principle Analysis of Working Conditions

All balance loops must have at least three kinds of motion states, including the lifting process of

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weights, the balancing static process and the falling process of weights.

2.1. Schematic Diagram of Hydraulic System

This paper mainly introduces a balancing circuit which realizes velocity regulating function by using proportional three-way valve. The circuit consists of 1. filter, 2. quantitative pump, 3. electric proportional three-way valve, 4. lifting valve, 5. hydraulic cylinder, 6. speed regulating valve, 7. descending valve, 8. fuel tank and other pipes, as shown in Figure 1.

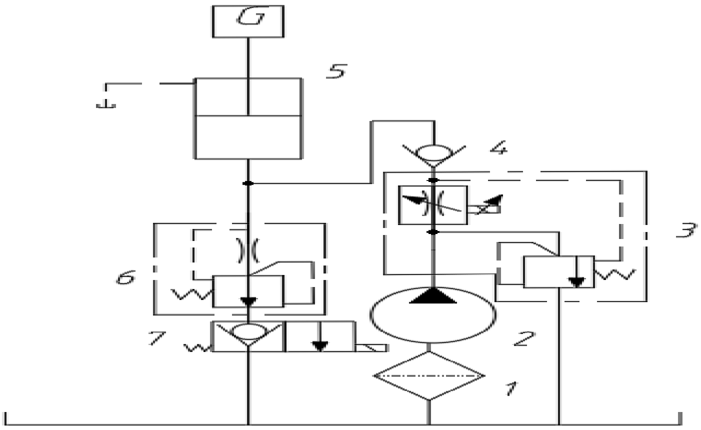

Figure 1. System Schematic Diagram

As shown in Figure 1, when the external load need rise, closing the descending valve 7 and feeding the appropriate voltage to the proportional three-way valve 3.

If load need descend, the current can be flowed into the descending valve 7, which can make the weight decrease by using the self-weight. Because of the restriction of the speed regulating valve 6, the system can achieve a steady descent. If the descending speed of the workpiece is still too fast, the appropriate current can be flowed into the remote proportional three-way valve 3 at the same time, or the electric signal can be sent to it. In this way, the speed of workpiece descent can be adjusted remotely.

For static condition, only power off operation is needed for descending valve 9. Due to the limitation of ascending valve 4, the workpiece can realize load static condition. When the hydraulic cylinder leaks in static condition for a long time, it is necessary to increase the oil outlet at a certain height of the upper chamber. At the same time, it can supply appropriate current to electric proportional three-way valve 3. Fill the leaked oil to keep the workpiece at rest for a long time.

3. AMEsim Simulation Model

3.1. Schematic Diagram of Electric Proportional Three-way Valve

According to the working principle of the electric proportional three-way valve, it is essentially a relief valve connected with an electric proportional throttle valve. The opening of the throttle is controlled by supplying current. Schematic diagram of the electric proportional three-way valve is shown in Figure 2.

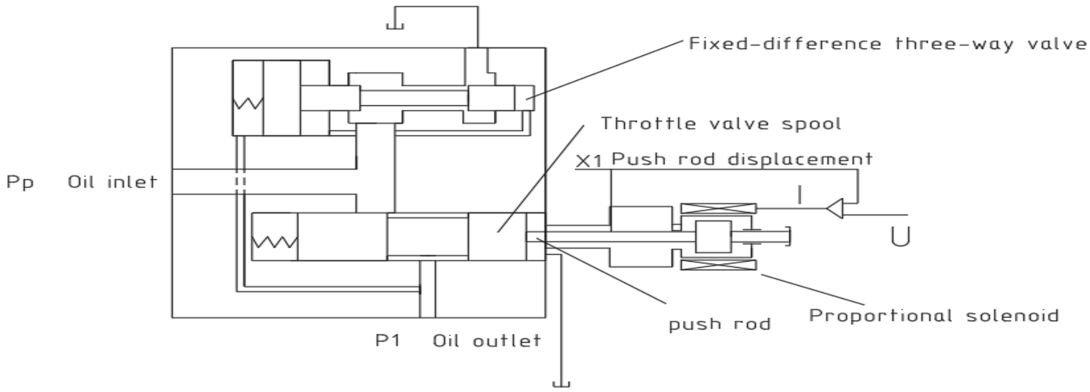

Figure 2. Schematic Diagram of Electric Proportional Three-Way Valve

Establish differential equations according to Figure 2

$$F_g = K_i i + K_v x_1 \tag{1}$$

In the formula, K_i is the current force coefficient N/A of proportional electromagnet and K_v is the equivalent spring stiffness N/m.

The differential equation of coil can be written as follows:

$$\mathrm{L}\frac{di}{dt} = K_u u - \left(K_u K_f + \mathrm{R}\right)i \tag{2}$$

Force balance equation of push rod

$$F_g = m_{\mathrm{v}}\frac{d^2x}{dt^2} + \mathrm{c}\frac{dx}{dt} + K_v x \tag{3}$$

Laplacian transformation of the above three formulas and simplification of the opening transfer function of the electro-hydraulic proportional valve are presented.

$$\frac{X_1(s)}{U(s)} = \frac{K_i K_u}{\left(Ls+K_u K_f+R\right)\times(m_{\mathrm{v}}s^2+\mathrm{c}s)} \tag{4}$$

3.2. Simulating model of System

Based on the above principles, the simulation model built by AMEsim software is shown in Figure. 4 for the circuit model and working principle corresponding to Figure. 1.

Set the external load mass as G=5t=50000N, the piston and moving parts mass as 0.2t. So the external force is settled to 52000N. the piston diameter of hydraulic cylinder as 102 mm, the plunger diameter as 50 mm, the flow rate of quantitative pump as 120 L/min, the descending speed of working condition as 0.14m/s, and the fixed throttle of initial speed regulating valve as 4.23mm through design calculation. The three-way valve and relief valve spool quality is set to 0.03kg proportional valve parameters check the mechanical design manual. The simulating model of system is shown in Figure.3.

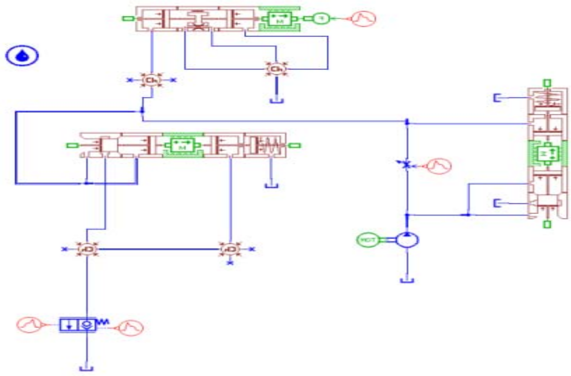

Figure 3. System Schematic Simulation Model

4. Simulation Analysis

4.1. Decline of Depending Entirely On Self-gravity

The above conditions are simulated in AMESim. When the initial conditions of the electric proportional three-way valve are not open, the simulation is carried out under the conditions of leakage and compression. The simulation results show that the falling speed of the workpiece is 0.14m/s. The simulation results of velocity, pressure and displacement are shown in Figure 4, Figure 5 and Figure 6 respectively.

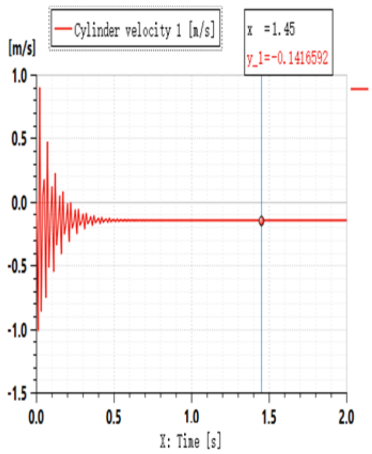

Figure 4. Velocity Chart of the Descending Condition of the Three-Way Valve when it is not Open

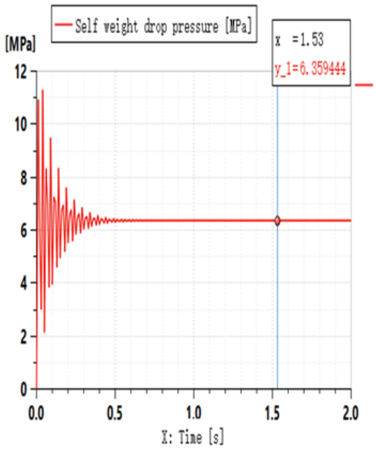

Figure 5. Pressure Chart of Drop Condition when the Three-way Valve is not Open

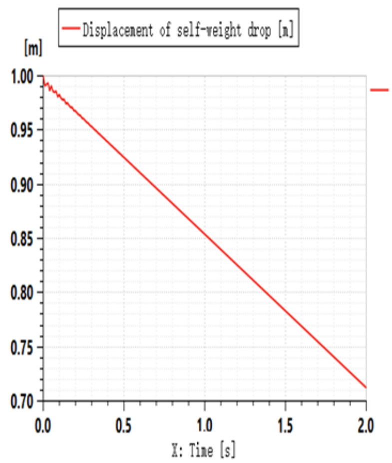

Figure 6. Displacement of Downward Working Conditions without Opening

Figure 4, 5 and 6 show that under the condition that the hydraulic pump is not supplied with oil, the equivalent load can be reduced steadily by feeding the current to the electromagnetic reversing valve. The descent rate is - 0.1416581m/s, which is relatively fast for some heavy loads. In order to improve the performance of the downward process under heavy load, the above conditions need to be adjusted.

4.2. The Influence of Opening Adjustment of Three-way Valve on System

The simulation analysis is shown in Figures. 7 and8 when the opening of the three-way valve is 4 mm, 2 mm and 1 mm respectively.

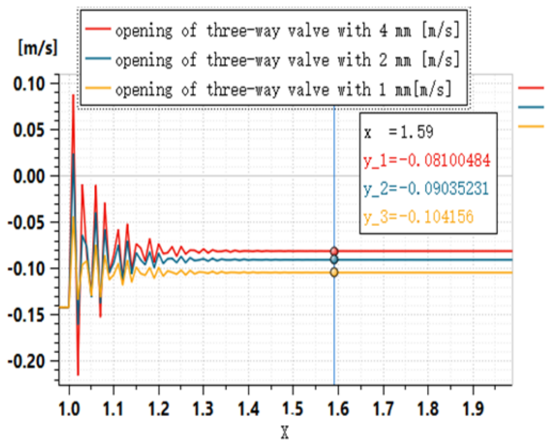

Figure 7. Different Velocity Diagrams for Throttle Opening of Three-way Valve

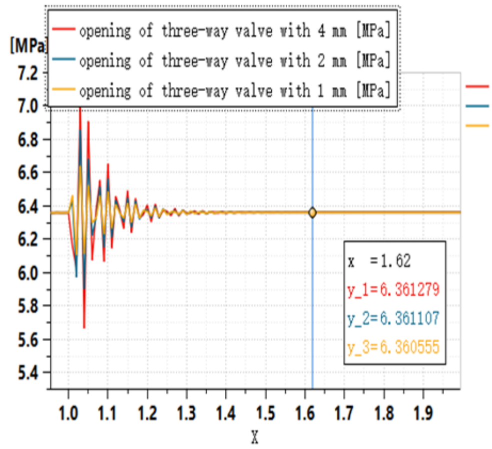

Figure 8. Pressure Diagrams with Different Openings

From the simulation results of Figure 7 and Figure 8, it can be seen that when time t = 1 s, the opening of the throttle is 4 mm, 2 mm and 1 mm, the corresponding velocity values are - 0.08099167 m/s, - 0.1041747 m/s and - 0.1279482 m/s respectively. The above results show that with the increase of valve opening, the speed of hydraulic cylinder will decrease. Compared with 0.1416581m/s when the valve is not open, the speed of load drop is significantly reduced under low speed and heavy load conditions. That is, the speed of piston motion is reduced, and the system has a rapid response speed and good performance. For the system pressure, the system pressure is determined by the load, so the pressure Figure is approximately the same, so the simulation results are consistent with the theoretical analysis results.

4.3. Simulation Analysis of Variable Load Conditions System

When the throttle opening of the proportional three-way valve is 4 mm, the load value is changed to work 1S under the initial condition of 52 000 N, and then the load suddenly changes to 55 000 N and 60000N.The simulation results are shown in Figures 10 and 11.

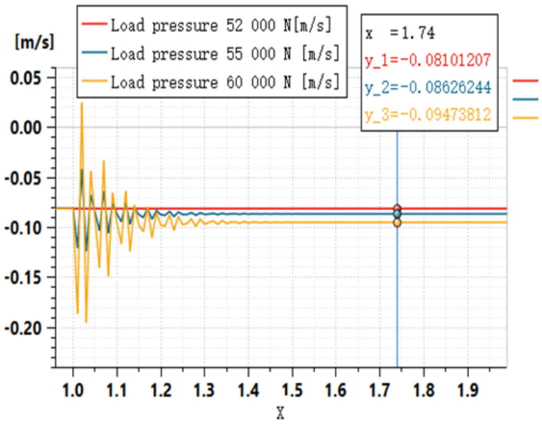

Figure 9. Velocity Change Diagram when Load Changes Abruptly

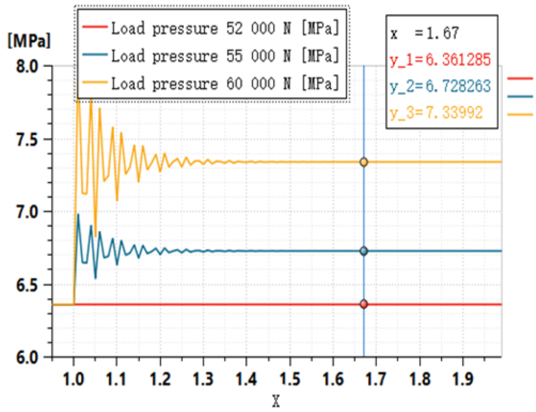

Figure 10. Pressure Variation Diagram under Sudden Load Change

The simulation results show that even if the load changes abruptly during operation, the overflow of the hydraulic cylinder will increase. That is, the velocity will increase, because the force acting on the spring end of the relief valve in the three-way valve increases, the flow rate of the three-way valve through the throttle will decrease, and the flow rate of the two-way valve will be fixed. The results show that the higher the pressure is, the faster the hydraulic cylinder will be. The pressure change will increase with the increase of load, so the simulation results are consistent with the theoretical analysis results.

4.4. The Influence of the Change of Throttle Port of Two-way Valve on the System

The influence of throttle change on the system is analyzed by changing the throttle of the two-way valve. The diameter of throttle orifice of two-way valve is 4.5 mm and 5 mm respectively under the condition that the opening of proportional valve is 4 mm. The change of throttle orifice has an effect on the characteristics of the system. The simulation results are shown in Figures 11 and12.

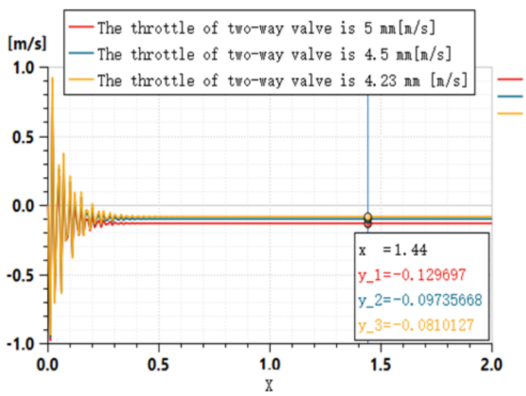

Figure 11. Variable Load Simulation Velocity Diagram of Throttle Orifice of Two-way Valve

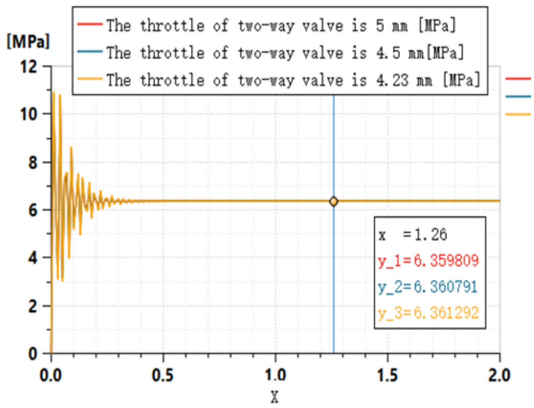

Figure 12. Variation Pressure Chart of Throttle Orifice of Two-way Valve

Figure 11 and Figure 12 show that when the throttle area of the two-way valve increases, the flow

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demand will increase, while the flow through the three-way valve will not change, so the flow from the hydraulic cylinder will increase, resulting in a relative increase in speed. The pressure is determined by the load, so the pressure is almost unchanged. The above results are consistent with the theoretical analysis of throttle flow.

5. Conclusion

In this paper, a balancing circuit of electric proportional three-way valve is constructed, and its application situation and principle are analyzed. The AMEsim software is used to simulate and analyze the characteristics of the loop. The factors affecting the speed and pressure of the system are analyzed, and the speed of the system is adjusted. Through the above analysis, the load pressure curves and velocity curves under different working conditions are obtained by changing various parameters affecting the system characteristics, which provides a better reference for the future study of the balance circuit.

6. Acknowledgement

Fund Project Sponsors: Major Research Project of innovative Group by Guizhou Education Department (Qianjiao he KY [2017] 029); Guizhou Science and Technology Support Plan (Qianke he Zhicheng [2017] 2027); Guizhou Provincial Science and Technology Support Plan (Qianke he Pingtai Rencai [2018] 5781-23).

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