Modeling and Simulation of Hydraulic Cartridge Valve Model Based on MATLAB

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Abstract

This paper adopts the hydraulic simulation special toolbox SimHydraulic in Matlab software, combined with the theory of hydraulic servo technology, establishes the simulation model of the key components such as proportional cartridge valve and electromagnetic reversing cartridge valve, and the sample data of the cartridge valve. The simulation model is experimentally verified. The simulation results are consistent with the actual characteristic parameters in terms of frequency response, pressure and flow characteristics, and the model is accurate and practical.

Keywords

Hydraulic cartridge valve , simulation, dynamic Analysis.

1. Introduction

In the 1990s, with the need for large-scale presses, injection molding machines and other large-scale equipment for the flow control valve with fast response and controllable large flow rate, the combination of proportional technology and cartridge valve was promoted, and electro-hydraulic proportional insertion was formed, which was an important turning point in the development of modern hydraulic technology. The combination of two-way cartridge valve and electro-hydraulic proportional control technology is mainly used in the large flow proportional control system. The application of the electro-hydraulic proportional cartridge valve, a large-tonnage and large-flow hydraulic system, greatly improves the overall performance of the high-flow hydraulic system. The improvement of equipment technology has great significance[1]. Modern hydraulic systems are becoming more and more complex, performance requirements are getting higher and higher, the coupling effects between components and circuits are complicated, and the design and calculation tasks are arduous, making it a hard task for human. SimHydraulics is a toolbox for physical modeling and simulation of actual electro-hydraulic systems by applying power bonding on the basis of Simulink. Using SimHydraulics can not only continue to use Simulink's basic functions, but also easily build multi-signal object-oriented electro-hydraulic liquid system simulation models. Using computer simulation calculations is simple and fast, and the calculation results are accurate. It is important for the design of large hydraulic systems.

2. Organization of the Text

2.1 The Basic Structure and Working Principle of the Cartridge Type Proportional Throttle Valve

This model uses a cartridge-type proportional throttle valve for the Atos LIQZO-L series of high-frequency two-way proportional flow cartridge valves. This type of valve uses a proportional servo valve as the pilot stage. The two-way cartridge valve with large diameter is used as the main stage. The opening displacement of the main stage spool is detected by the LVDT displacement sensor and fed back to the amplifier. The control algorithm and parameters constitute an electric feedback closed-loop control system for the displacement of the main stage spool. The physical structure of the LIQZO-LE valve in this series is shown in Figure 1.

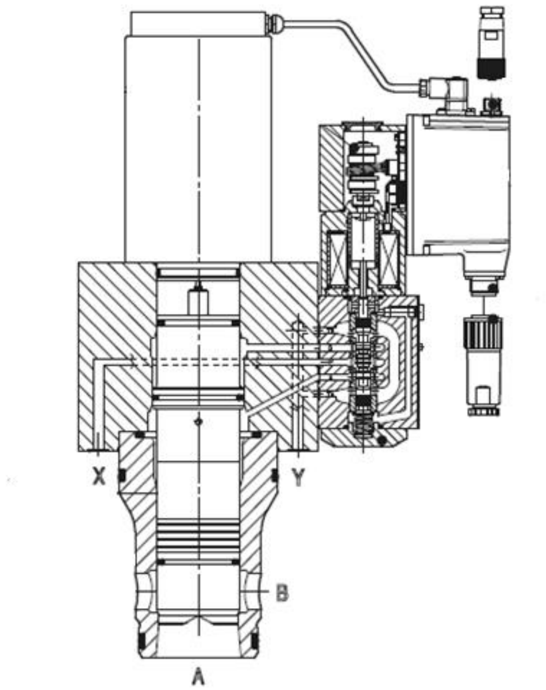


Fig. 1 Cartridge Displacement-Electric Feedback Pilot Electro-Hydraulic Proportional Throttle

As shown in Figure 2, after the input signal voltage is processed and amplified by the control amplifier, a direct current is input to the proportional electromagnet, and the electromagnet converts the current proportionally into the spool displacement of the pilot control valve, and then the pilot controls the hydraulic bridge to proportional. The smaller power amplification of the electromagnet output finally converts the electrical signal into a hydraulic signal or controls the power stage hydraulic control main valve, that is, the two-way cartridge valve, so that the hydraulic control main valve generates a certain valve opening, thereby outputting a certain value. A pressure signal or flow signal to control the action of the actuator. The displacement sensor on the main spool converts the displacement signal into an electrical signal, which is then compared to the setpoint and then performs the deviation control[2].

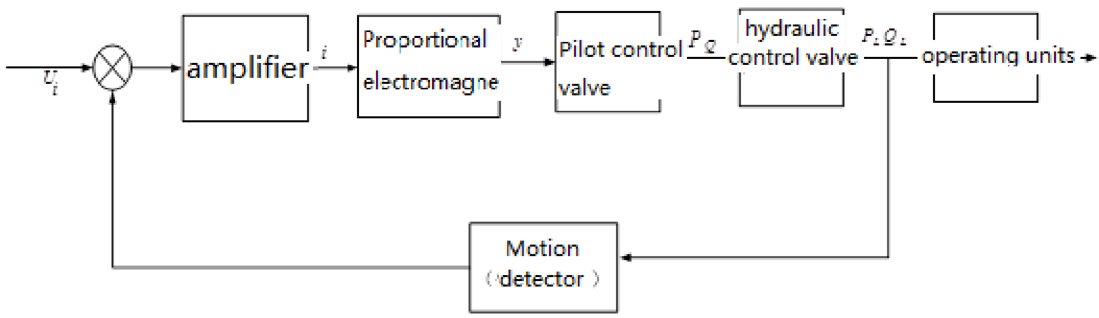


Fig. 2 Displacement-electric feedback control block diagram

2.2 Model Establishment and Dynamic Characteristic Simulation of Cartridge Proportional Throttle Valve

2.2.1 Model Parameter Calculation of Pilot Proportional Valve

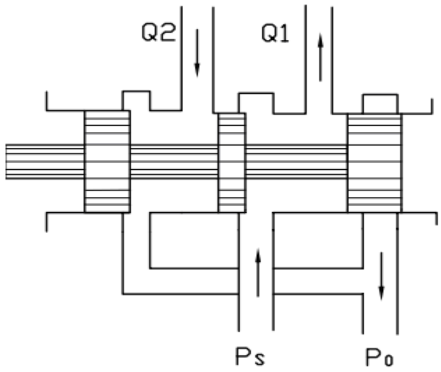


Fig. 3 Internal fluid flow of the proportional valve

The plug-in proportional throttle valve used in this system is the Atos LIQZO-L-502L4 model. The internal schematic diagram of the pilot valve is shown in Figure 3. It is known from the Atos sample that the main valve has a diameter of 50. Below the diameter, the pilot valve is 6-way diameter, the natural frequency of the pilot proportional valve is 40HZ, and the nominal flow rate of the valve is 40L/min under the pressure of 7MPa.

$$Q = C_d \cdot \omega \cdot X_V \sqrt{\frac{2(P_s - P_L)}{\rho}} \tag{1}$$

Q ——Proportional valve port flow (m^3/s);

C_d——Proportional valve flow system, take 0.72;

ω——Area gradient of proportional valve, $\omega = \pi \cdot d = 3.14 \times 0.06 = 1.884 \times 10^{-2}$ m 。

X_V——Opening displacement of proportional valve spool (m);

ρ——Oil density, (860 kg/m^3);

P_s——System work pressure (Pa);

P_L——Proportional valve port return pressure (Pa)。

When the formula is normal, the valve opening is between -0.38mm and +0.38mm.

2.2.2 Model Parameter Calculation of Pilot Proportional Valve

The main structure and dimensions of the main spool and seat are shown in Figure 4.

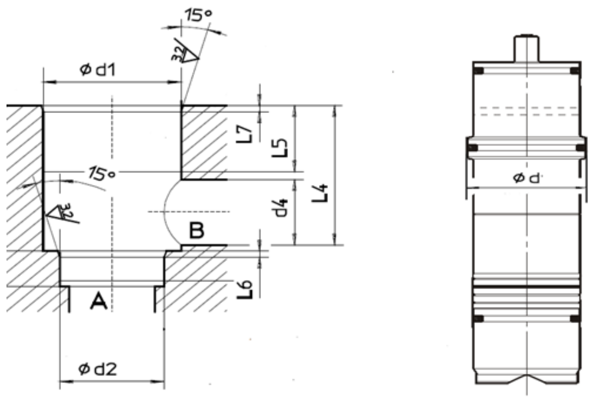


Fig. 4 main spool, main valve base

$d = 92.143$mm d_1=90mm $L_7 = 4$ mm d_4=50 mm $d_2 = 68$mm $L_6 = 3$mm

The main valve has a diameter of 50mm and a spool diameter of 90mm. At the upper surface of the valve core, the action surface of the spool is d=92.143mm. The spool quality is estimated to be 5.78kg and the main spool travels 15mm.

In summary, the simulation parameters of the plug-in proportional throttle valve are shown in Table 1:

Table 1. Simulation parameters

name	parameter	Numerical value
Pilot proportional valve	Pilot valve spool stroke range /mm	-0.38 ~ 0.38
	Natural frequency /HZ	40
	Damping ratio	0.8
Main valve	Spool quality /kg	5.78
	Main valve stroke /mm	45
	Main valve upper and lower chamber action surface diameter /mm	92.1
	Main valve diameter /mm	50

2.2.3 Cartridge Proportional Throttle Model

Figure 5 is a simulation model of a plug-in proportional throttle valve. The two control oil chambers in the main spool are constructed by two Translational Hydro-Mechanical Converter modules in the Simhydraulic toolbox. The mass of the spool is replaced by the Mass block in the mechanical module library. The pilot servo valve is available from the hydraulic module library. Instead of the module, the proportional electromagnet is replaced by a Proportional and Servo-Valve Actuator block, and the feedback controller PID is built using the control module in simulink, where kp=13, ki=2.4, kd=0.043.

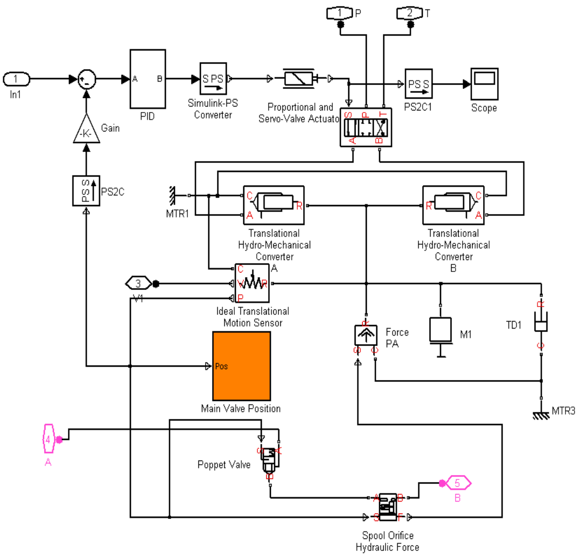
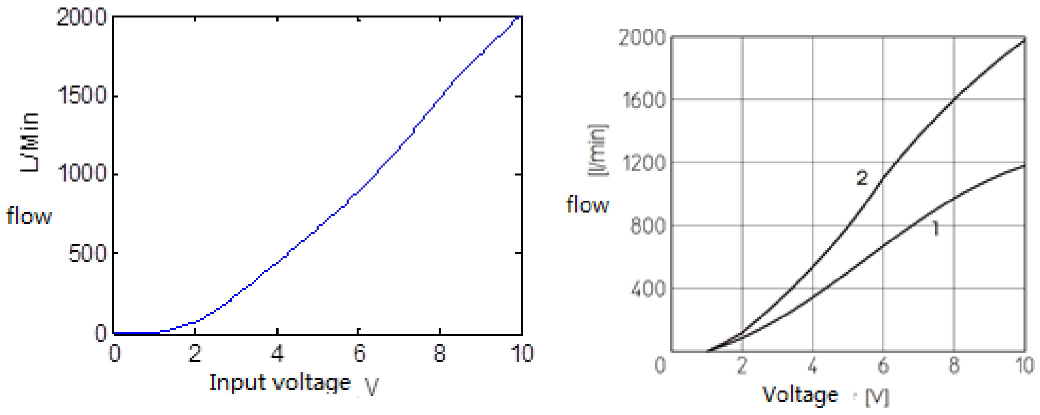


Fig. 5 simhydraulic model of the cartridge proportional throttle valve

2.2.4 Cartridge Proportional Throttle Valve Simulation Model Verification

When the main valve pressure difference is 5 bar, the simulation curve and sample curve flowing through the main valve flow rate under different input signals are shown in Fig. 6 a) and 6 b) (curve 2), respectively. It is seen that the flow curve of the simulation model is basically consistent with the sample curve, indicating that the simulation model established in this paper is correct.



a) b)

Fig. 6 Simulation model flow and sample flow curve

It is known from the sample that the voltage signal range is 0~10V (corresponding to the valve core opening is 0%~100%). The dynamic response curve of the valve is obtained by adjusting the PID control parameters as shown in Fig. 7. The dynamic response curve of the valve is shown in the figure. The stepping time of the rising and falling edges of the main spool is 23 ms and 25 ms, respectively. The sample on the valve is 20 ms. From the simulation results shown in Fig. 7, the dynamic response speed of the valve can basically meet the requirements.

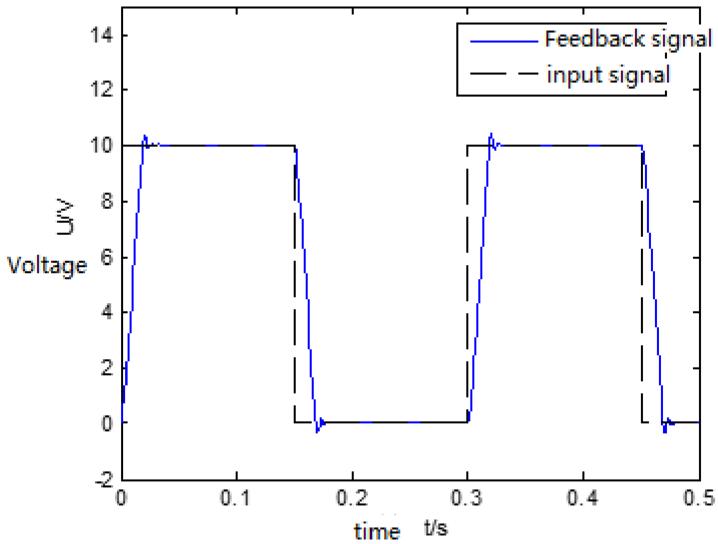


Fig. 7 Square wave response curve of main spool displacement

3. Modeling and Simulation of Electromagnetic Reversing Cartridge Valve

The cartridge valve has the advantages of fast response, large flow rate, good sealing performance, high reliability and high integration. It is precisely because of these advantages that the two-way cartridge valve requiring high hydraulic pressure at high pressure, large flow rate and rapidity is widely used on brick machines. At present, it has become one of the mainstream technologies of modern press integrated control. It is mainly used in the pressing, pressurizing and returning process of the brick press. Its opening and closing characteristics directly affect the rapidity and stability of the brick press[3].

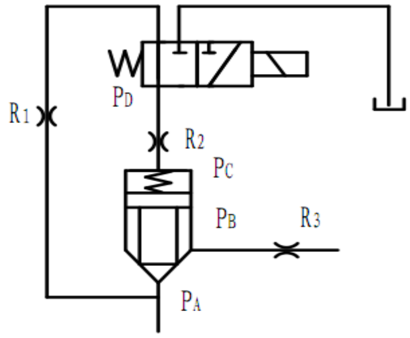
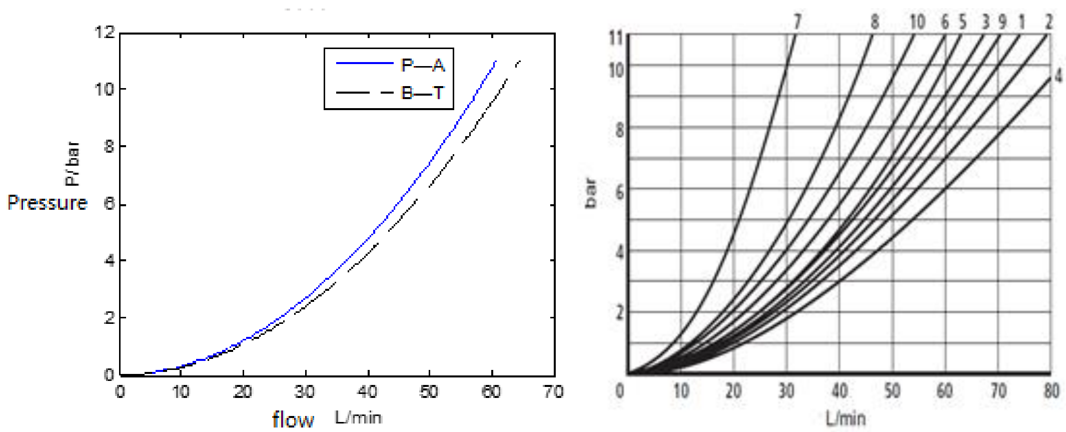


Fig. 8 Schematic diagram of the electromagnetic reversing valve cartridge valve

The cartridge valve used in this system is TLC040A010E, with a nominal diameter of 40mm The pilot two-position four-way electromagnetic reversing valve is 4WE6Y-6X/EG24N9K4/B12, with a nominal diameter of 6mm. Figure 8 is the electromagnetic reversing cartridge valve. Schematic diagram[5].

3.1 Model Parameter Determination of Pilot Two-Position Four-Way Reversing Valve

According to the Rexroth sample, the flow curve of the 4W6Y-6X two-position four-way valve PA and PB port is shown in curve 5 of Figure 9 b), while the flow curve of AT and BT port is shown in curve of Figure 9 b). It can be seen that the valve port of this valve is not symmetrical, so the valve port flow formula $Q = C_d \cdot \omega \cdot X_V \sqrt{\frac{2(P_s - P_L)}{\rho}}$, It is calculated that the maximum opening of the P-A port is 1.65 mm when the spool reaches the maximum stroke, and the maximum opening of the A-T port is 1.56 mm. After selecting the existing two-position four-way reversing valve from the Simhydraulic library and set the parameters, the simulation shows that the flow curve under different pressure drops is shown in Fig. 9 a), which is basically consistent with the valve flow curve on the sample, so The simulation model is basically correct.



(a) (b)

Fig. 9 Simulation of the flow curve of each valve port and the flow curve of each valve port of the sample

3.2 Determination of Model Parameters of the Main Spool of the Cartridge Valve

The two-way cartridge valve in the 38M hydraulic press hydraulic system uses Rexroth's TLC040A010E valve.

According to the sample, the diameter is 40mm, the opening pressure is 1.0bar, the valve core does not have a damper head, the X-end area is 16.62 cm^2, the A-end area is 11.1 cm^2, the spring stiffness is 14000N/M, and the spool half-cone angle is $\alpha = 15^{\circ}$.

3.3 Electromagnetic Reversing Cartridge Valve Model

The model of the electromagnetic reversing cartridge valve ,with the two-way four-way reversing valve as the pilot valve, and the two-way cartridge valve as the main valve, is shown in Fig. 10:

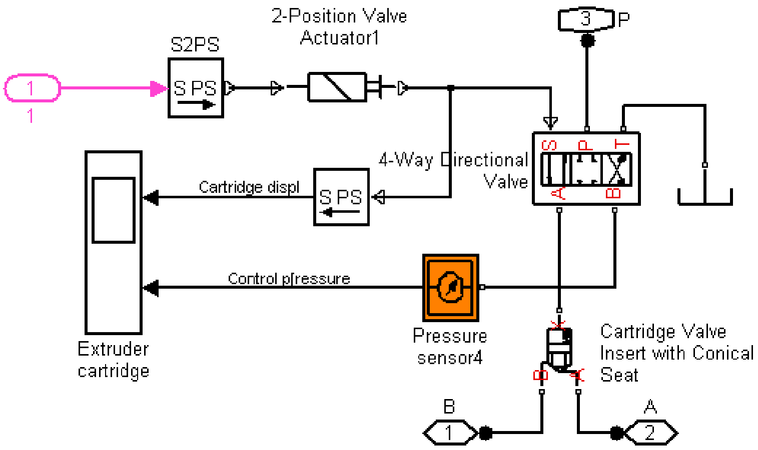
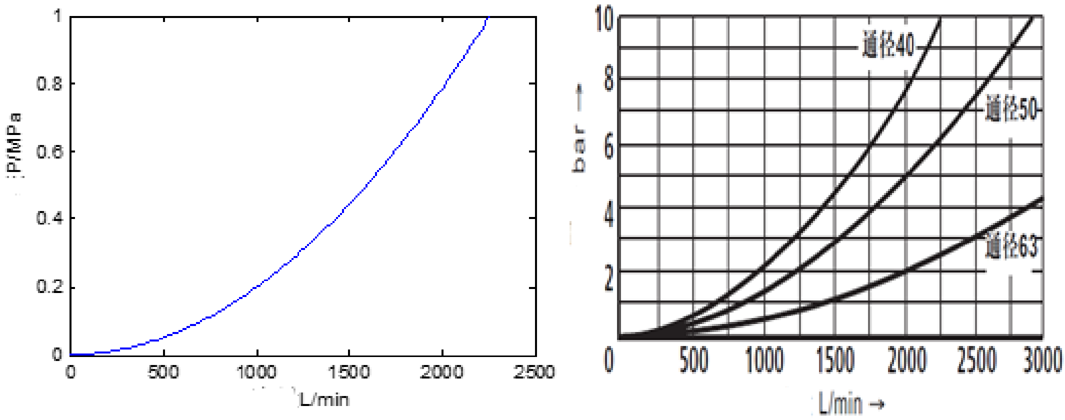


Fig. 10 Electromagnetic reversing cartridge valve simulation model



a) b)

Fig. 11 simulation flow curve and sample valve flow curve

After setting the required simulation parameters, the simulation shows the flow curve under different pressure drops as shown in Fig. 11 a), which is basically consistent with the valve port flow curve on the sample as shown in Figure 11 b) (through diameter 40). So the simulation model is basically correct.

4. Conclusion

This chapter uses the hydraulic system modeling toolbox in Matlab software to model the key component proportional cartridge valves and the general cartridge valves in the hydraulic system. The parameters in the model are set more accurately on the basis of the relevant data of the samples, and the relevant data of the self-produced components in the enterprise. The accurate component model is obtained by comparing the simulation results with the pressure, flow curve and response time of the sample, which establishes the necessary foundation of the simulation analysis of the next hydraulic system in the pressing process.

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