Experimental Study on Flow Characteristics of Hydraulic Multi-Way Valve Based on CAN Communication

Junhua Deng* and Xiajie Jin*
School of Mechanical Engineering and Automation, Shanghai University, Shanghai, 200444, China

*Corresponding author e-mail:18717881173@163.com, jinxiajie1@126.com

Abstract. This paper develops a CAN communication multi-way valve measurement and control system. This paper elaborates on the introduction of hydraulic circuit, the construction of measurement and control system. In the LabVIEW platform, the author designs the application program through the CAN communication card, writes the signal generator to control the multi-way valve, and then draws the flow characteristic curves of the multi-way valve.

1. Introduction
Hydraulic multi-way valve as the core component of engineering machinery system, its performance directly affects the performance of the whole machine [1]. Danish hydraulic company Danfoss designed a CAN communication module for its multi-way valves. In this paper, a set of measurement and control system is designed for the multi-way valve to analyze the flow characteristics of the multi-way valve.

2. Designing the hydraulic circuit and introducing tests
For the multi-way valve measurement and control requirements, the hydraulic principle diagram of the measurement and control system is shown in Figure 1.

![Hydraulic schematic](image)

1. Motor  2. Torque Tachometer  3. Hydraulic Pump  4. Ball Valve  5. Check Valve  6. Proportional Relief Valve  7. Pressure Sensor  8. Filter  9. Flow Sensor

**Figure 1.** Hydraulic schematic
As the picture shows, the motor 1 is used to drive the hydraulic pump 3 to supply the oil source to the system, and the motor output speed and torque are collected by the torque tachometer 2. The system pressure is applied by the proportional relief valve 6.1, and it is collected by the pressure sensor 7.1. During the test, the A’ port and B’ port of the bridge circuit are respectively connected to the A port and B of the test piece of multi-way valve. The bridge circuit formed by the check valve 5.2-5.4 realizes the automatic switching of the A and B directions. The proportional relief valve 6.2 loads the multi-way valve working port. The pressure sensor 7.2 collects the working port pressure. The flow sensor 9.2 collects the output flow of the working port of multi-way valve. The hydraulic oil of the multi-way valve T port is directly returned to the oil tank through the flow sensor 9.1.

According to the national technical requirements for multi-way valves [2], hydraulic multi-way reversing valve test method [3] and enterprise requirements, this paper designs the flow characteristic test of control signal and spool displacement, hysteresis characteristic and nonlinearity test and flow characteristic test under load.

3. The construction of system
In order to meet the communication, measurement and control requirements of multi-way valve, the structure of the measurement and control system is shown in Figure 2. It consists of industrial computer, PLC, data acquisition card, CAN communication card, etc.

![Figure 2. System framework](image)

4. Test Software Design
The test software uses National Instruments’ innovative software product LabVIEW11.0 as a development tool, which can be completely customized according to user requirements. The software has good reliability, ease of use, accuracy, etc [4]. The software can filter and process the collected data. And we can carry out modular and hierarchical structural design according to the thinking of virtual instruments [5].

According to the functions that the measurement and control software needs to implement and the modular design concept, this design divides the software into data acquisition and processing module, setting CAN communication module, drawing curves module, report generation module and other auxiliary modules.

The test flow chart is shown in Figure 3.
4.1. Configuring CAN Communication Parameters
Compared with other communication methods, CAN bus has many advantages, mainly reflected in the bus allocation scheme. In the communication system, the bus is divided into data bus and address bus [6]. Each piece of the multi-way valve is assigned a fixed ID at the factory. When testing, all units are terminated at the end via the CAN bus, a CAN high voltage line and a CAN low voltage line. When the hardware is connected, the corresponding communication unit can be communicated by setting the ID value in the CAN communication parameter configuration interface. The interface for configuring CAN communication parameters is shown in Figure 4.

4.2. Processing communication messages
After the system completed communication with the multi-way valve, the multi-way valve can continuously send messages to the system, and the messages content includes the status of the spool, error alarms and other information. The system monitors the information in real time. If an error alarm signal is found, the message will be automatically parsed to display the cause of the error on the front panel of the software. The operator needs to further check and eliminate the alarm.
In order to meet the requirements of the flow characteristic curves generation, this design will automatically configure the control signal through logic operation, and collect the spool displacement signal in real time. The signal processing block diagram is shown in Figure 5. The multi-way valve has 250 position states in each direction and is controlled by digital signals. In order to make the flow rate change evenly, this design uses a linearly increased signal control method to send flow control signals to the multi-way valve. After the multi-way valve receives the control signal, the spool moves correspondingly to change the opening degree of the working oil port, thereby controlling the output flow rate of the multi-way valve. The spool of the multi-way valve has a maximum displacement of 7 mm. During the test, the spool displacement signal is fed back to the system in real time. This design analyzes the feedback spool displacement signal and processes it for the flow characteristic curve.

![Figure 5. The signal processing block diagram](image)

4.3. Drawing the flow characteristic curves

In order to reflect the flow characteristics of the multi-way valve, this design uses the flow control signal sent by the system and the spool displacement signal fed back by the multi-way valve and the output flow of the multi-way valve working port collected by the system to draw curves. The block diagram is shown in Figure 6.

Because the design of the multi-way valve control signal transmission and the feedback spool displacement signal is collected directly by the CAN communication card and the multi-way valve, the delay of the acquisition signal and the real-time value is 50ms. The flow signal is converted by the secondary instrument, the filtering delay of the signal isolation module, the signal acquisition processing of the data acquisition card, and the mean filtering of the upper computer software, so that the delay of the flow signal and the real-time value displayed by the upper computer software is up to 1000 ms. In order to make the flow characteristic curves drawn by the software truly reflect the real-time flow characteristics, the collected flow control signal and the spool displacement signal are delayed for 950ms, and then used to draw the curves. Although the three signals involved in the curves have a delay of 1000ms at this time, the flow characteristic curve does not reflect the influence of time factors, so the operation can increase the accuracy and authenticity of the curve drawing.
5. Analysis of test results

This test used the Danfoss PVG-32 multi-way valve unit assembled with the AMP PVED-CC communication module.

5.1. Control signal and spool displacement flow characteristics

The flow characteristic curves of the control signal and spool displacement is shown in Figure 7. According to the product sample, the working port starts to output flow when the spool displacement is 1.7mm and the flow control signal is 70. The maximum output flow rate is reached when the spool displacement is 6.2 mm and the flow control signal is 230. The test results show that the A-direction working port starts to output flow when the control signal is 75 and the spool displacement is 1.9 mm. the B-direction working port starts to output flow when the control signal is 65 and the spool displacement is 1.8 mm. the A-direction maximum output flow rate is reached when the control signal is 220 and the spool displacement is 6.1 mm. the B-direction maximum output flow rate is reached when the control signal is 225 and the spool displacement is 6.2 mm. After the test flow characteristics are compared with the product samples, the test results are accurate.

Figure 6. Block diagram of the curve drawing

Figure 7. The flow characteristic curve of the control signal and spool displacement
5.2. Hysteresis characteristics and nonlinearity

The hysteresis characteristic and nonlinearity characteristic curves of the multi-way valve are shown in Figure 8. The software of this design will automatically calculate the hysteresis characteristics and nonlinearity of the tested valve when drawing the characteristic curve. The calculation results show that the A-direction hysteresis of the multi-way valve is 5.01%, the B-direction hysteresis is 5.43%, the A-direction nonlinearity is 10.67%, and the B-direction nonlinearity is 9.11%.

Under the standard test conditions, the hysteresis index of the general multi-way valve is 6%, and the nonlinearity index is 7.5%. By comparison, the nonlinearity of the multi-way valve is too large.

![Figure 8](image)

Figure 8. The hysteresis characteristic and nonlinearity characteristic curves

5.3. Flow characteristics under load

In order to study the flow characteristics of multi-way valves under load, the test set the load pressure to 5MPa, 10MPa, 15MPa, 20MPa and 25MPa respectively. The flow characteristic curves under different loads are shown in Figure 9. The test results show that the maximum output flow of the multi-way valve decreases as the load increases. However, under different loads, the flow has a higher stability during the rise.

![Figure 9](image)

Figure 9. The flow characteristic curves under different loads
6. Conclusion
The design of the measurement and control system fully meets the company's requirements for the flow characteristics test of the CAN communication multi-way valve, which can accurately reflect the control characteristics of flow control signal and the spool displacement to the output flow of the multi-way valve. The actual use shows that the measurement and control system has the characteristics of convenient operation, high measurement accuracy and stable operation. Due to the communication delay and other factors, the spool displacement signal has a slight delay compared to the flow control signal. The effect of this phenomenon on the flow characteristics of the multi-way valve is worthy of follow-up research.

References
[1] Jingang Liu, Jianren Zhu, Shuizhang Qi, Jianwen Chen. Development of Integrated Test System for Excavator Multi-way Valve Based on Labview [J]. Mechanical Science and Technology, 2014, (9).
[2] JB/T8729-2013 hydraulic multi-way reversing valve [S]. 2013.
[3] JG/T5116-1999 Technical conditions for integral multi-way valves for hydraulic excavators [S]. 1999.
[4] Leping Yang. LabVIEW Advanced Programming [M]. Beijing: Tsinghua University Press, 2005.
[5] Yongfu Lv, Xiajie Jin, Shizhen Gao, Keli Xing. Research on the test system of no-load flow characteristics of electro-hydraulic servo valve [J]. Machinery Manufacturing, 2015, (8).
[6] Yanguo Zhang. Analysis of the advantages of CAN bus technology [J]. Heilongjiang Science and Technology Information, 2014, (6).