Study of Gas Proportional Valve Performance Monitoring and Control System

X.H. Zhao
Department of Mechanical and Electrical Equipment
Jinan Railway Vocational and Technical College
China

***Abstract*-Working principles, characteristic parameters and adjustment of gas proportional valve are introduced in the paper. Performance parameters of gas proportional valve can be tested through gas proportional valve monitoring and control system. Test data are processed and analyzed, characteristic curve graph capable of reflecting performance of the proportional valve has been obtained, and the quality of the gas proportional valve has been judged by comparison with criteria.**

Keywords-gas proportional valve; monitoring and control system; performance

I. INTRODUCTION

Performance of gas proportional valve is concrete manifestation of quality. Traditional proportional valve performance testing method is characterized by low precision, high load and low efficiency. Microcomputer is applied in instruments and testing systems, thereby leading to fundamental change of structure. Microcomputer can solve problems which can' t solved or can' t be solved easily by traditional instruments on one hand, it also can simplify circuit, increase functions, improve accuracy and reliability, lower costs and prices, accelerate new product development speed, and achieve some functions of human brain. Higher and higher requirements are proposed on quality of various gas appliances and performance of gas appliance parts in modern times due to rapid development of the gas industry. Currently, there are rare professional instruments for testing performance of proportional valve in China, therefore it is very necessary to research and develop intelligent testing system of gas proportional valve performance. It can be used for automatically testing and judging whether all performances of the proportional valve are qualified or not, thereby guaranteeing safety and quality of production and life of people to certain extent[1-2].

Various tests must be conducted in order to assess performance of proportional valve. Test data are processed and analyzed in order to obtain characteristic curve reflecting the proportional valve performance[3]. Various obtained data and characteristic curve are compared with criteria, thereby judging whether the proportional valve is qualified or not.

Performance of gas proportional valve is concrete manifestation of quality. Traditional proportional valve performance testing method is characterized by low precision, high load and low efficiency. A variety of testing systems are composed more and more sophisticatedly with development of science technology and productivity. Higher and higher requirements are proposed on testing precision and reliability of many parameters. It is required that the testing system has higher speed, precision, reliability and automatic level, thereby minimizing labor and improving working efficiency on one hand. It is required that the detection system should be provided with greater flexibility and adaptability, which can be developed conveniently to multi-functionality and intelligence on the other hand. In addition, research cycle should be shortened and cost should be reduced[4]. Therefore, it is very necessary to research and develop performance intelligent testing system of the gas proportional valve. It can be used for automatically testing and judging whether the proportional valve is qualified or not, thereby guaranteeing safety and quality on production and life of people to certain extent.

II. HARDWARE SYSTEM DESIGN

A. Pressure Sensor

In the system, two pressure sensors are adopted for measuring inlet and outlet pressures of proportional valve. 24PCDFA 6D produced by Honeywell Company is adopted as the two pressure sensors, and the power supply is 10VDC. 24PC series pressure sensors are provided with patented conductive sealing elastic connection system. It eliminates conventional wire bonding and ribbon connection, increases media measurement compatibility. Meanwhile, it is also provided with patented Snap-together structure, which makes measurement aperture form diversified. 2mA constant current power supply can be used for significantly improving sensitivity drift; Negative pressure, positive pressure and absolute pressure can be measured. Wheatstone bridge circuit design with low power and without amplification and compensation can provide inherent and stable mV level output.

B. Flow Sensor

AWM 720P1 flow sensor is adopted to achieve large flow range under small package. AWM 720P1 has a 6ms response time, 10V DC power supply and power consumption of only 60mW. AMP compatible connector of sensors provides a reliable electrical connection. The sensor is also very suitable for application of portable devices and batteries. AWM 700 series sensors are provided with characteristics of high reliability and high accuracy. The circuit is provided with amplification effect and temperature compensation.

C. Control System of Proportional Valve

Proportional valve control system is realized by direct digital control (DDC). DDC system replaces simulation

© 2015. The authors - Published by Atlantis Press

controller by a computer, which is used for circulation detection on various controlled variables during the production process. The variables are calculated according to predetermined control algorithm. Then control signals are sent, which are directly acted on control valve through output channels, thereby realizing closed-loop control of the process[5]. In the paper, pressure and flow signals sent by sensor are converted into digital signals by input channel A/D converter, which are sent to IPC. IPC/data acquisition card is used for comparing and analyzing collected electric signals with set values. Output channel D/A converter is used for converting digital signals calculated and output by computer into current signals for controlling operation of proportional valve.

III. Analysis of Gas Proportional Valve Performance Monitoring and Control System

Test of gas flow is essential in gas proportional valve performance test system. Therefore, gas flow detection methods are firstly introduced in the paper. Test method of thermal mass flowmeter in the system is mainly introduced, and general design plan of the system is given. Gas proportional valve monitoring and control system belongs to special monitoring and control system for test, adjustment and finished product detection of electric characteristics of PCV proportional regulating valves in various specifications and models, which can realize high-speed, accurate and intelligent testing. The research system consists of two major parts of hardware and software. The working principle is shown as follows: I and P1 are output by programmable power supply and pressure controller according to calculation and program setup. Detected P2 and Q are sent to computer for processing data by sensing device through interface. Performance curve and data of gas proportional valve can be drawn.

A. Gas Proportional Valve

When gas proportional valve is operated, gas is firstly fed into switch valve by gas inlet, which is sent to gas chamber through switch valve port. Air holes are set on cover plate of switch valve proportional valve. Gas and air are mixed in the proportional valve. Gas and air mixture is sent to gas appliances through proportional valve port by gas outlet. Proportional control valve spool is cooperated with proportional valve coil for controlling gas and air intake. Sealing performance of proportional valve directly affects working accuracy and service life of valve. Therefore, it is necessary for studying sealing performance of proportional valve[6]. Gas proportional valve is provided with a solenoid valve for controlling connection and disconnection of combustion gas. Meanwhile, one or two proportional valves must be arranged for proportionally regulating ventilation of gas outlet, thereby achieving the purpose of accurately and efficiently controlling combustion[7].

B. Working Principle of Gas Proportional Valve

Gas proportional valve consists of a PID intelligent adjustable proportional valve and one to three switch valves generally. System composed of gas proportional valves can detect corresponding physical parameters in real time by temperature, pressure, flow, and other sensors, which are transmitted to microcomputer controller for operation. Valve membrane tonicity and valve port openness can be regulated by changing the controlled current, moving the valve rod and controlling the displacement, thereby controlling gas consumption according to tiny proportion, and achieving the purpose of precise and sensitive control.

C. Characteristic Parameters of Gas Proportional Valve

Static performance and application status of proportional valve can be described by three output characteristic curves.

1) Pressure Regulation Characteristics: Pressure regulation characteristics (P2~P1) are shown in Fig 1. Ability of proportional valve to guarantee constant output pressure P2 during pressure P1 change can be reflected. The main parameters including pressure regulation starting point, pressure regulation line change trend, pressure regulation return difference, pressure regulation performance under different currents (flow capacities), etc.

2) Stable Control Characteristics: Stable control characteristic reflects relationship between proportional valve output pressure (P2)/flow rate (Q) and control input current (I). Output quantity and control signal are proportional. Typically, when output quantity experiences one-round cycle change between zero to rated value along control current, the obtained stable control characteristic is a hysteresis curve[8]. Wherein, the test value connected line is called nominal stable control characteristic line as shown in Fig 2. and Fig 3. The drawing shows that the flow rate is always provided with starting current as output quantity control characteristic. Corresponding starting output quantity is zero. The pressure is provided with the minimum working pressure or starting pressure as output quantity control characteristic.

3) Data Acquisition System: Data acquisition system is a series of process sum of transmitting to-be-tested parameter information to computer through sensor. In the study, suitable pressure, flow rate and other sensors are selected for measuring front-end signals. The signals are converted into 4-20 mA industry current signals through transmitter module. Data acquisition card is used for collecting converted standard industrial signals. Then information can be transmitted to computer. Then, information is transmitted to computer after corresponding processing, thereby completing information upward flowing process. Signal conditioning includes signal filtering, small signal amplification, signal attenuation, level shifting, impedance matching, current/voltage conversion, etc. according to demand. The sample holder is designed in order to solve error during faster change of measured signal. A/D converter is necessary in the system since only digital signals can be accepted by the computer.

4) Estimation and Treatment of Test Data: The measurement data includes two parts of random error and systematic error from the measurement practice. There are gross errors sometimes. The three parts have different natures. Influence and treatment methods of measurement results are also different. The researcher mainly handle according to

measurement data analysis study, judgment and analysis condition in actual measurement process, thereby obtaining scientific measurement results. When data are collected by data acquisition system, data collected by the system is deviated from the true values due to various interferences. Software can be used for sample data preprocessing. The sampling data can be close to the true value, therefore secondary processing results of data can be more accurate. In the paper, digital filtering algorithm is used for sampling data processing. Digital filtering algorithm is adopted to overcome errors introduced by random interference. It has the following advantages:

i) Hardware is not demanded by digital filtering. It is only a calculation process with high performance and without impedance matching problem. Especially digital filtering can be adopted for filtering signals with high or low frequency, which can not be compared by analog filter.

ii) Digital filtering is realized by software algorithm. One software "filter" can be shared by many input channels, thereby reducing hardware cost.

iii) As long as the filtering procedures and operation parameters of software filter are properly changed, filtering characteristics can be changed, which is especially effective for low frequency pulse interference and random noise.

5) Test Data: In the experiment, PCI-1711 data acquisition card is used for collecting values of P1, P2, Q and I. Final test result obtained after treatment are shown in Table 1, 2 and 3.

TABLE I. TEST PARAMETERS OF P1 AND P2 UNDER DIFFERENT CONTROL CURRENTS.

I=8mA		I=12mA		I=16mA		I=20mA	
P1/KPa 0	P2/KPa 0	P1/KPa 0	P2/KPa 0	P1/KPa 0	P2/KPa 0	P1/KPa 0	P2/KPa 0
0.102	0.125	0.204	0.202	0.301	0.301	0.504	0.502
0.312	0.314	0.519	0.52	0.501	0.499	1.016	1.029
0.519	0.354	1.130	1.049	1.015	1.016	1.569	1.514
1.012	0.36	1.523	1.109	1.523	1.513	2.321	2.259
1.518	0.366	2.018	1.127	2.033	1.723	2.638	2.489
2.609	0.379	2.541	1.151	2.537	1.757	2.820	2.522
3.101	0.389	2.870	1.156	3.011	1.835	3.123	2.538
3.410	0.39	3.319	1.169	3.302	1836	3.309	2.537

TABLE II. TEST PARAMETERS OF P2 AND I.

I/mA	4	6	8	10	12
P2/KPa	0.291	0.651	0.719	1.094	1.431
I/mA	14	16	18	20	-
P2/KPa	1.620	1.997	2.415	2.758	-

TABLE III. TEST PARAMETERS OF Q AND I.

I/mA	4	6	8	10	12
Q/KPa	0	0.1701	0.624	1.124	1.942
I/mA	14	16	18	20	-
Q/KPa	2.648	2.701	2.831	3.021	-

(G) Drawing of characteristic curve graph

P2 ~ P1, Q ~ I and P2 ~ I characteristic curves of gas proportional valve is drawn based on the experimental data shown in Figure 3.1, Figure 3.2 and Figure 3.3 respectively. Wherein, P1 is proportional valve inlet pressure, P2 is proportional valve outlet pressure, I is proportional valve control current, and the operator can judge whether the proportional valve is qualified or not according to the drawn curve.

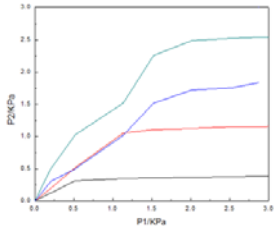

FIGURE I. CHARACTERISTIC CURVE OF PROPORTIONAL VALVE P2-P1.

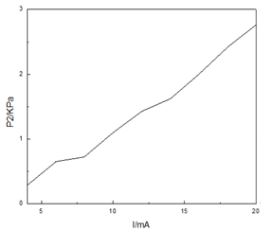

FIGURE II. CHARACTERISTIC CURVE OF PROPORTIONAL VALVE P2-I.

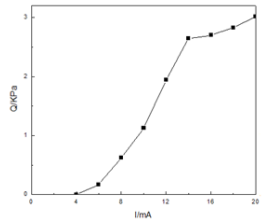

FIGURE III. CHARACTERISTIC CURVE OF PROPORTIONAL VALVE Q-I.

IV. CONCLUSION

Currently, gas proportional control technology has been applied to a variety of industries of national economy, which has important impact on technological breakthroughs and productivity in all industries. Gas proportional valve is an important chemical energy-thermal energy conversion unit in combustion system for connecting gas technology and combustion efficiency. Its working condition has great influence on electronic control unit and system performance. Therefore, performance testing thereof is far-reaching. In the paper, monitoring and control system is studied and designed for key performance test of gas proportional valve. The system has advantages of reliable data transfer, simple operation, and user-friendly interface. Various functions can be conveniently

managed by tree hierarchy structure file management. Experiment data is directly shown, analyzed, processed and saved in real time according to demand. New approaches are made for experimental equipment automation and networking. The study work also should be further deepened in the following aspects: study design of gas proportional valve clamping system facilitating smooth progress of test work; study of experiment gas emission and collection beneficial for safety and environment protection; general monitoring and control system design suitable for various gas proportional valves and design of more stable, reliable and feasible software.

REFERENCES

[1] Wang Yu-Ping, *The Theory and Method of Evolutionary Computation*, Beijing: Science Press,2011.

[2] Farahi, M. H. & Ansari, E. A new approach to solve muti-objective linear bilevel programming problems. *Journal of Mathematics and Computer Science*, 1(4), pp.313-320,2010.

[3] LU Hong, FENG Liang, LIU Yong-fang, et al. Analysis Example of Structure and Principle of Gas Proportional Valve. Gas & Heat, 33(10), pp.17-21,2013.

[4] ZHANG Xiang-wei, FENG Liang, JIANG Di. Analysis on Control Scheme of as ProportioningValve, 29(2),pp.24-26,2009.

[5] KONG Xiang-zhen, LIU Yan-jun, WANG Yong, et al. Compensation and simulation for the deadband of the pneumatic proportional valve. Journal of Shandong University(Engineering Science), 36(1),pp.99-102,2006.

[6] WANG Gui-na, SU Xiao-guang. Research on performance test syste m of gas proportional valve. Transducer and Microsystem Technologies, 27(2),pp.30-34,2008.

[7] LEI Lin. Microcomputer automatic detection and system design, Beijing: Electronic Industry Press,2003.

[8] NI Wen-bo, WANG Xue-mei, LI Fu, et al. Study on electro-pneumatic proportional valve based on PWM technology. Electric Drive For Locomotives, 3,pp.12-15,2005.