

RESEARCH OF A CONTROL VALVE CHARACTERISTICS TEST

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ABSTRACT

Control valves are commonly found in modern process plants. The control valve reliability is critical to the control quality and safety of a plant. Whether a control valve meets the challenge of the control requirement depends on its response characteristics. To obtain the characteristics of the control valve, an experiment test system is developed to assess the performances of the control valve, the graphical description for the performances of the control valve is proposed, and the test method is presented.

Keywords: *Test Technology, Control Valve, Process Control, Response Characteristics*

1. INTRODUCTION

The market demands for higher quality products have increased the need for reduced process variation [1]-[3]. One factor in the quality of the final end product is the improvement of the control loop performance. A critical component in the loop is the control valve [4]-[5]. Whether the control valve meets the challenge of the control requirement depends on its response performances [6]-[7]. The static performance indexes of the control valve mainly include intrinsic error, repeatability error, reproducibility error, rated travel deviation, dead band, start error, stop error, etc. The dynamic performance indexes usually contain step-response rise time, step-response peak time, step-response regulating time, step-response overshoots, etc. In order to get the static and dynamic characteristics of the control valve, we need to build a test system and establish the test method.

In this paper, section 2 presents the design of the test system which is used to obtain the performances of the control valve. Section 3 proposes the graphical description and the test method for the performances of the control valve. Section 4 gives conclusions to the whole paper.

2. DESIGN OF THE TEST SYSTEM

The schematic diagram of the performance test system of the control valve is shown in Fig. 1. The controller is a computer controller. The signal of pressure or flow measured using the pressure or

flow meter is compared with the signal of the desired pressure or flow by the controller. The controller output accordingly adjusts the opening/closing actuator of the control valve in order to maintain the actual pressure or flow close to the desired pressure or flow.

The communication between the PC and the peripherals is realized by the PCI-6238 data acquisition card which is produced by the National Instruments Company of the United States. The main technical parameters of PCI-6238 are as follows:

(1) 60V Isolated (Analog Current: 8 Analog Inputs, 2 Analog Outputs, Digital 30V: 6 Inputs, 4 Sourcing Outputs).

(2) For the analog input, the sampling rates is 250 kS/s, the resolution is 16 bits, the maximum input current is in the range of -20mA ~ + 20mA, precision scope is 18.8 μA , and the range of sensitivity is 0.24 μA .

(3) For the analog output, the update rate is 500 kS/s, the resolution is 16 bits, the maximum current range is in the range of 0-20mA, and the precision scope is 52.3 μA .

(4) For the digital channels, the input voltage is in the range of 0-30 V, the output voltage is in the range of 0-30 V.

The operational interface of the software control system is shown in Fig. 2.

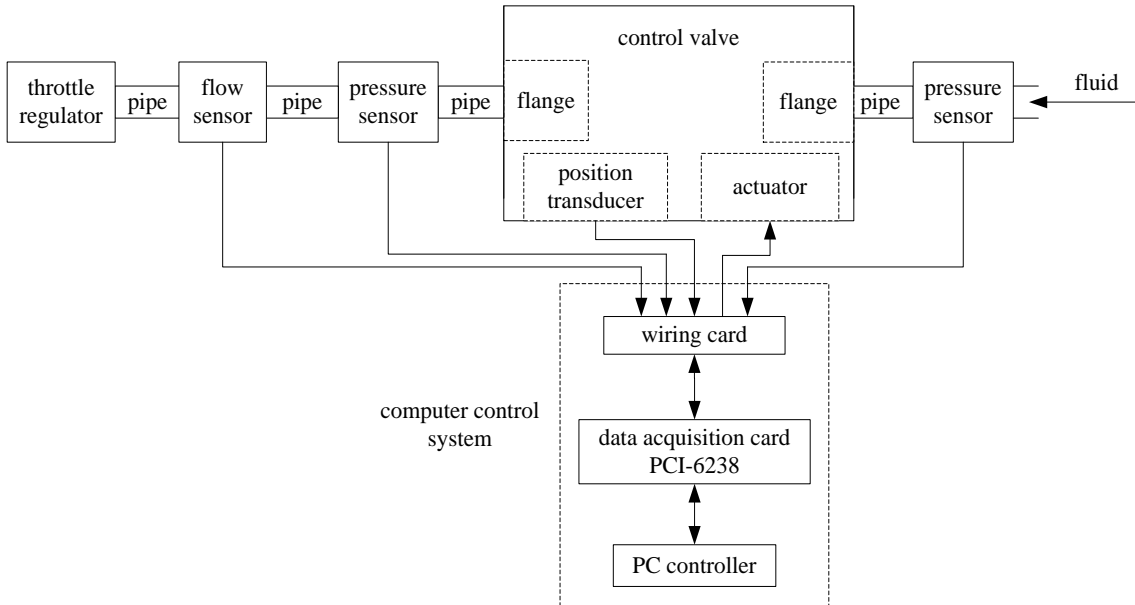


Fig. 1 Schematic Diagram Of The Performance Test System

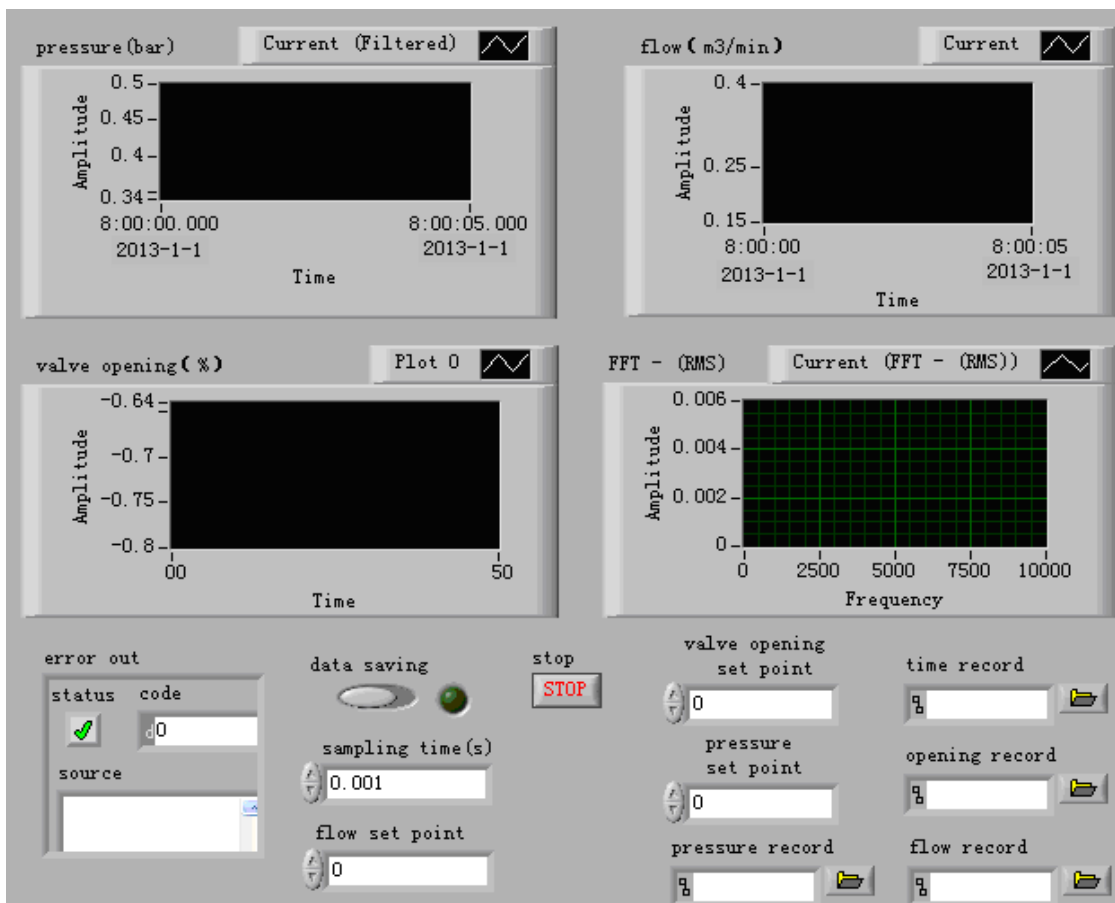


Fig. 2 Operational Interface Of The Software Control System

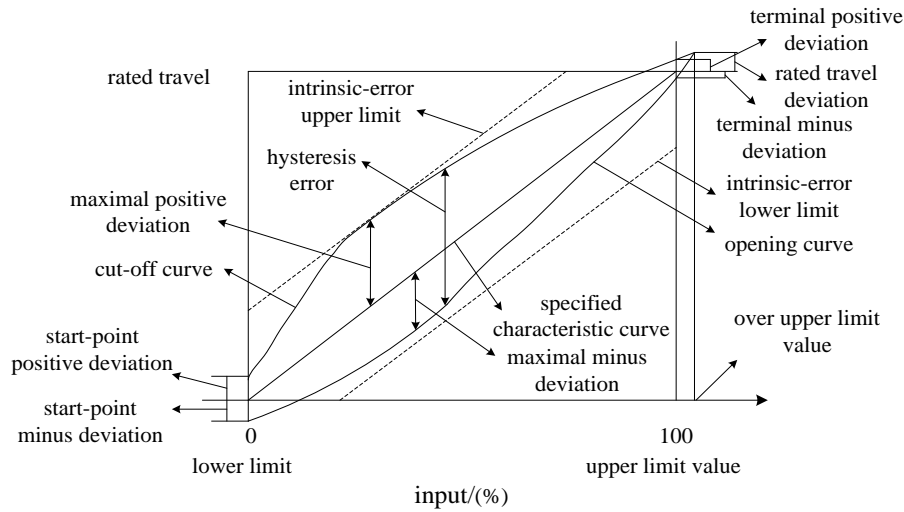


Fig. 3 Graphic Description For The Static Performance

3. TEST METHOD

According to the relevant test standard, the control valve is in no-load condition for the static performance test. In the test, we should input the slowly changing signal successively in the positive direction and the negative direction, so as to make the actuator of the control valve operate continuously and smoothly in the whole travel. When test the travel, we should regard the position where the core of the control valve is totally close as the test reference. Fig.3 shows the graphic description for the static performance of the control valve [8].

After the test, we can get the static performance indexes of the control valve according to the following method.

(1) intrinsic error

In the specified reference conditions, the calculation formula of the intrinsic error can be written as

$$\delta_m = \frac{|l_t - l_s|}{l_e} \times 100\% \quad (1)$$

where l_t denotes the test travel value of the test point, l_s expresses the specified travel value of the test point, and l_e is the rated travel of the control valve.

(2) repeatability error

The calculation formula of repeatability error can be described by

$$\delta_{re} = \frac{l_i - l_j}{l_e} \times 100\% \quad (2)$$

where l_i is the maximum travel measurement of the test point, and l_j denotes the minimum travel measurement of the test point (in the condition of test input signals in the same direction for many times).

(3) reproducibility error

The reproducibility error can be expressed as

$$\delta_{rc} = \frac{|l_m - l_n|}{l_e} \times 100\% \quad (3)$$

where l_m is the maximum travel measurement of the test point with valve open signals, and l_n expresses the minimum travel measurement of the test point with valve close signals.

(4) start error、stop error

The start error and the stop error can be written, respectively, as

$$\delta_{sa} = \frac{l_d}{l_e} \times 100\% \quad (4)$$

$$\delta_{so} = \frac{|l_g - l_e|}{l_e} \times 100\% \quad (5)$$

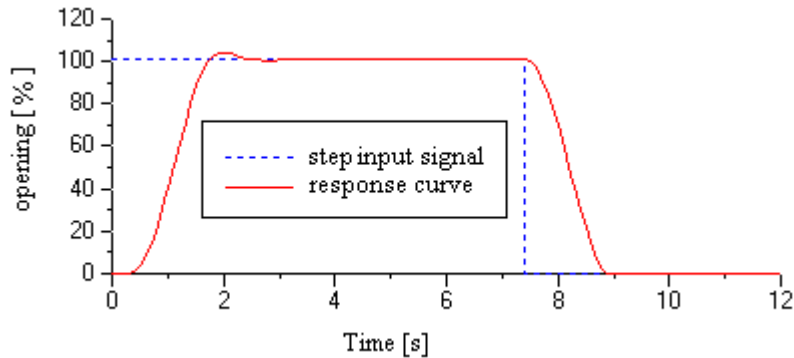


Fig. 4 Step Response

where δ_{sa} expresses the start error, δ_{so} is the stop error, l_d is the travel measurement when the input signal is in the lower limit, and l_g is the travel measurement while the input signal is in the upper limit.

(5) rated travel error

The rated travel error can be described by

$$\delta_{ra} = \frac{|l_a - l_e|}{l_e} \times 100\% \quad (6)$$

where l_a is the travel measurement when the input signal is in the over upper limit.

(6) hysteresis error

The hysteresis error can be written as

$$\delta_{hy} = \frac{|l_b - l_c|}{l_e} \times 100\% \quad (7)$$

where l_b denotes the travel measurement of the test point with the valve open signal, and l_c is the travel measurement of the test point with valve close signal.

As shown in Fig. 4, we can obtain the dynamic characteristics through step response test.

4. CONCLUSIONS

Control valves are generally present whenever fluid flow regulation is required. The control valve characteristics are critical to the control quality and safety of a plant. By means of the test technique, the characteristics of the control valve can be obtained. In this paper, an experiment test system is

developed to assess the performances of the control valve and the test method is presented.

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REFERENCES:

- [1] K. Yonezawa, R. Ogawa and K. Ogi, "Flow-induced Vibration of a Steam Control Valve", *Journal of Fluids and Structures*, Vol. 35, 2012, pp. 76-88.
- [2] M.A. Mohammad and B. Huang, "Compensation of Control Valve Stiction Through Controller Tuning", *Journal of Process Control*, Vol. 22, No. 9, 2012, pp. 1800-1819.
- [3] M. Potter and M. Bacic, "Design and Control of Hardware-in-the-loop Simulations for Testing Non-return-valve Vibrations in Air Systems", *IEEE Transactions on Control Systems Technology*, Vol. 20, No. 1, 2012, pp. 98-110.
- [4] YS. Tverskoi, N.A. Agafonova and E.D. Marshalov, "Diagnosing the Characteristics of Control Valves used in Power Unit Control Systems", *Thermal Engineering*, Vol. 59, No. 2, 2012, pp. 139-146.
- [5] Y.D Xie, Y.J. Liu and Y. Wang, "Prediction Model of Control Valve Characteristics",



- Advanced Materials Research*, Vol. 605-607, 2013, pp. 1345-1349.
- [6] D. Bottazzi, F. Franzoni and M. Milani, "Metering Characteristics of a Closed Center Load-Sensing Proportional Control Valve", *SAE International Journal of Commercial Vehicles*, Vol. 2, No. 2, 2010, pp. 66-74.
- [7] J. Ruan, R. Burton and P. Ukrainetz, "An Investigation into the Characteristics of a 2D Flow Control Valve", *American Society of Mechanical Engineers, The Fluid Power and Systems Technology Division*, Vol. 7, 2000, pp. 127-133.
- [8] Y.Q. He, X.Z. Qiu and J. Yang: "Design and Application of Control Valve", Chemical Industry Press, Beijing of China 2005.