Research and Implementation of Constant Pressure Control with Electro-pneumatic Proportional Valve

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Abstract. In this paper, the implementation method of "constant pressure control" in industrial production is proposed. Through experiments, the feasibility of using pneumatic proportional and open-loop control technology is proved. The control system has the characteristics of high precision, convenient debugging and good economy, and has high practicability.

Keywords: Electro-pneumatic; Pneumatic system; Given value; Actual value.

1. Introduction
The constant pressure control in industrial production usually adopts the method of mechanically adjusting the intake valve. When the supply pressure produces large fluctuations, it will affect the control accuracy. At the same time, the intake valve wears large, increasing the maintenance cost. With the development of industrial automation, the combination of pneumatic components and electronic components makes the electronic control circuit develop rapidly. In this paper, the electric proportional control scheme has the advantages of low price, simple structure, fast response speed, high power volume ratio and no pollution. The control system uses the proportional valve to convert its continuous electrical signal input into continuous pneumatic signal output, and then controls the air quality entering or discharging the two chambers of the cylinder, so it can adjust the pressure of the two chambers of the cylinder, and finally complete the constant pressure output of the cylinder.

2. Principle of Electro-pneumatic Proportional System
In many industrial applications, because there is a special mechanical relationship between the controlled pressure and the area, and there is a linear proportional relationship between the given value of the voltage of the electric pneumatic proportional valve and the output pressure, we only need an open-loop control system to adjust the output variable pressure with accuracy. The open-loop system of constant pressure control with electro-pneumatic proportional valve is shown in Figure 1. In this open-loop control system, the pressure control valve adopts Rexroth's pneumatic proportional valve. Its principle is to provide 24V power through a plug, and the given value of analog voltage is transmitted to the internal controller through an A / D converter. After a pulse width regulation process and V / I conversion, the controller controls the action of the coil. The actual pressure value of the air pressure output port is converted into voltage and transmitted to the internal controller, and then the analog output is carried out through the D / A converter on the plug.
3. Establishment and Realization of Constant Pressure Experiment System

The experimental model is built on a pneumatic clamping system, which uses two single-acting cylinders to clamp and fix three different sizes of parts with three clamping forces (F1 = 50N, F2 = 150N, F3 = 250N). In order not to deform the parts, constant pressure control is required to achieve clamping and fixing.

3.1. Pneumatic System

The pneumatic system is mainly composed of an air source, a pneumatic triplet, an electro-pneumatic proportional valve, a pressure sensor with an analog output signal, an integrated measuring system and an external cylinder with springs, and a single-acting cylinder without springs. Pneumatic circuit diagram as shown in Figure 2.

3.2. Calculation of Given Value of Electro-pneumatic Servo Valve

According to the selected cylinder parameters, the diameter of the cylinder piston is 25mm, and the effective area \( A = 4.91 \text{cm}^2 \) can be calculated. According to the formula \( F = p \times A \), the pressure corresponding to the three clamping forces can be calculated, and then the proportional valve pressure / The voltage characteristic curve gives the voltage setting value of the electro-pneumatic proportional valve, as shown in Table 1.
Table 1. Proportional value table of pressure and voltage of proportional valve.

| Clamping force F(N) | Area A(cm$^2$) | Pressure $p_v$(bar) | Given voltage value $U$ (v) |
|---------------------|----------------|---------------------|-----------------------------|
| 100                 | 4.91           | 2.04                | 1.7                         |
| 300                 | 4.91           | 6.11                | 5.1                         |
| 500                 | 4.91           | 10.18               | 8.5                         |

In order to calculate the clamping time, it is also necessary to calculate the volume of the system. In the calculation process, the volume of the servo valve can be ignored. Only the volume of two cylinders and three gas pipes are calculated. According to the length of three gas pipes is 30cm, the volume of the whole system (the piston rod extends to the end) is 0.101L. According to the pressure-flow characteristic curve of the proportional valve as shown in Figure 3, the flow(S) at different gas supply pressures can be obtained.

According to the Boyle-Major law, the initial volume $V$ of the system at the initial pressure (assumed to be 1 bar) can be obtained, and then the clamping time $T$ of the cylinder can be obtained according to the formula (1) of the pumping rate of the vacuum pump, as shown in table 2.

$$T = 2.3 \times V_s \times \log_{10}\left(\frac{p_1}{p_2}\right)$$

Table 2. Cylinder clamping time.

| Initial pressure $p_1$(bar) | Final pressure $p_2$(bar) | Flow $s$(l/s) | Initial volume L(l) | Clamping time T(s) |
|-----------------------------|---------------------------|--------------|---------------------|-------------------|
| 1                           | 2                         | 1.25         | 0.2                 | 0.111             |
| 1                           | 3                         | 1.75         | 0.3                 | 0.188             |
| 1                           | 4                         | 2.17         | 0.4                 | 0.256             |
| 1                           | 5                         | 2.58         | 0.5                 | 0.311             |
| 1                           | 6                         | 3.00         | 0.6                 | 0.358             |
| 1                           | 7                         | 3.67         | 0.7                 | 0.371             |

3.3. Implementation of the System

It can be seen from Table 1 that a 100N clamping force is equivalent to an over pressure of 2.04bar, which corresponds to a given value voltage of 1.7v; set the setting values to 1.7, 5.1, and 8.5 in turn, and start the system tracking function to obtain the pressure / The system response diagram of the given value step function is shown in Figure 4. It can be seen that the middle curve is that the actual value is close to the given value, and there is no obvious overshoot, which meets the requirements of the electric-pneumatic proportional control system.
4. Conclusion
The electro-pneumatic proportional system has successfully achieved constant pressure control, while also achieving pressure repeatability and stability. Therefore, in practical applications, this control method can be used when constant pressure control is required. It is found in the experiment that there is a time interval of about 20ms between the start of the given value change and the actual value change. This delay is caused by the controller inside the proportional valve. It cannot be fully opened immediately; although there is a delay, the actual system performance is still close to the calculated system performance, the actual application is not affected.

References
[1] Lianren Zhang, 2018 Research on the establishment of a new open-loop model of pneumatic proportional pressure valve (Beijing: Hydraulics Pneumatics & Seals vol 4) p25
[2] Dong Liu, Jianzhong Zhang, Junjie Li 2013 Selection and Application of Vacuum Pump of Oil-Gas Recovery Device in Adsorption Process (Beijing: Oil Depot and Gas Station) p 29
[3] Bosch Rexroth 2008 Pressure regulating valve-electric proportional valve Proc. (Bosch Rexroth product manual) p 6
[4] Congxu Lu, Haibo Niu 2018 Development and application research on boyle-marioyle law (Beijing: Physics and Engineering) p 90
[5] Jingkang Liu, Fei Long 2018 Design and implementation of programmable pneumatic proportional control system (Beijing: Computer Measurement & Control vol 7) p89

Figure 4. System response of pressure / given value step function.