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PNEUMATIC PROPORTIONAL VALVE WITH PIEZOELECTRIC ACTUATOR

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Abstract: The paper deals with a pneumatic proportional valve using a piezoelectric actuator, designed by the authors. The experimental model, a pneumatic positioning system based on the new proportional equipment and the control algorithm are considered. The tests performed with the presented positioning system revealed that it is possible to obtain a positioning accuracy of ±0.3 mm.

Key words: proportional valve, piezoelectric actuator, positioning system

1. INTRODUCTION

The resistive method by varying a local flow area is used in pneumatics in order to adjust the flow. There are many technical solutions (Pashkov et al., 2004; Avram et al., 2008) characterized by the shape of the seat and of the mobile element, the type of the movement between them, the adjustment method. A pertinent review of the actual trends of the pneumatic equipment domain reveals sustained researches in order to integrate other types of actuators - generically known as "unconventional" - in their structure. The goal is to improve the static and dynamic performances of the devices and to miniaturize their sizes. The unconventional actuators category includes: piezoelectric actuators, magneto-strictive actuators, actuators without mobile elements (Vogel & Mühlberger, 2003).

The paper deals with a pneumatic proportional valve with a piezoelectric actuator developed and tested by the authors.

2. THE EXPERIMENTAL MODEL

The experimental model designed by the authors consists of two main subassemblies: the Physik Instrumente P-287 actuator '1' and the pneumatic proportional valve '2' (Fig. 1). The control of the flowing area is assured by a conical equilibrated valve '3', whose position in respect to the seat '4' is determined by the value of the actuator power voltage.

The flow variation measured as a function of the control voltage (Fig. 2), shows significant hysteresis. A frequently used method to reduce the hysteresis consists in permanently tracking the valve position by means of a position feedback. For this purpose, the experimental model was equipped with a capacitive position transducer '6'. A piezoelectric force transducer '7' measures the force used to open the valve.

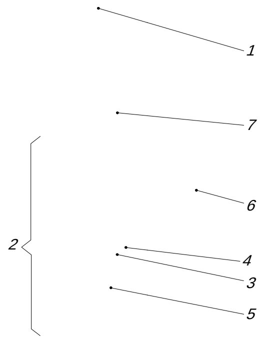

Fig. 1. The 3D model of the experimental setup

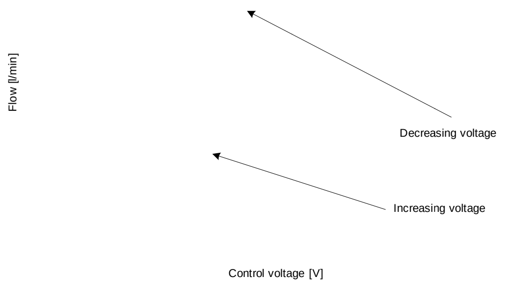

Fig. 2. The flow as a control voltage function

In order to asses the dynamic behavior of the proportional valve described above, two such valves, DPP_1 and DPP_2 were included in a pneumatic positioning system (Fig. 3) consisting of a linear pneumatic motor 'MPL', a positioning transducer 'T_p', two one-way pneumatic controlled valves 'Sd_1' and 'Sd_2', two one-way valves 'Ss_1' and 'Ss_2', and two pneumatic distributors 'DC3/2' and 'DC 5/3'. The system works in a closed loop. The position of the load is permanently tracked by the position transducer and compared to the position programmed by the electronic command system. The mobile assembly will move until the two values become equal. Using such a system, the load can be positioned in any point of the working area, very close to the programmed position. The accuracy depends on the resolution of the position transducer.

The positioning algorithm was written using the LabView 7.1 environment (Munteanu, 2009) and its mathematical model is given in Table 1.

Fig. 3. The scheme of the pneumatic positioning system

$y_0 < y_P$ (right direction)	$y_0 > y_P$ (left direction)
Starting stage: $\begin{cases} u\_1 = 24V \\ u\_2 = 0V \\ u = 24V \end{cases}$	*Starting stage:* $\begin{cases} u\_1 = 0V \\ u\_2 = 24V \\ u = 24V \end{cases}$
Case 1 $y < y_P - a_f$ $u_{PIEZO\_1} = u_r$ $u_{PIEZO\_2} = 0$	*Case 1:* $y > y_P + a_f$ $u_{PIEZO\_2} = u_r$ $u_{PIEZO\_1} = 0$
Case 2: $y_p - a_f \le y < y_P - \varepsilon$ $u_{PIEZO\_1} = u_f$ $u_{PIEZO\_2} = 0$	*Case 2:* $y_P + a_f \ge y > y_P + \varepsilon$ $u_{PIEZO\_2} = u_r$ $u_{PIEZO\_1} = 0$
Case 3: $y_p - \varepsilon \le y \le y_P + \varepsilon$ $\begin{cases} u\_1 = 0V \\ u\_2 = 0V \\ u = 0V \\ u_{PIEZO\_1} = 0V \end{cases}$ $u_{PIEZO\_2} = 0$	*Case 3:* $y_p + \varepsilon \ge y \ge y_P - \varepsilon$ $\begin{cases} u\_1 = 0V \\ u\_2 = 0V \\ u = 0V \\ u_{PIEZO\_2} = 0V \end{cases}$ $u_{PIEZO\_1} = 0$

Tab. 1. The equations for the positioning algorithm

The notations in Tab. 1 are: y_0- the starting position; y_P-the final target position; a_f-the braking distance; ε-the positioning accuracy; u_r-the working phase voltage value; u_f-the braking phase voltage value.

Over the braking range characterized by the a_f distance from the final target position y_p, both voltages of the piezoelectric actuators become u_f. Consequently, the load speed decreases in the target proximity, which is a favorable issue from the positioning accuracy point of view. The a_f, u_r and u_f are set by the operator after some testing trials.

3. THE EXPERIMENTAL SETUP

In order to choose the proper actuator for the experimental setup, the conical valve has been dimensioned and the resistant force has been computed. Therefore, the input data are: the maximum controlled flow q_{max}=100 l/min; the supply pressure: p_a =10 bar; the seat diameter: d=8mm and the nominal diameter: d_n=2mm.

A set of measurements was achieved by running the designed software and analyzing the data acquisition. Figure 4 shows the positioning accuracy defined as $\varepsilon_r = y_P - y_r$, where ε_r is the effective error and y_r is the position reached when the programmed final position is y_P. Figure 5 shows the repeatability of the system when the initial position is y_i=10 mm and the imposed target position is y_f=390 mm, so that a positioning error have been measured; then y_i have been programmed to be the target position and the new error have been measured.

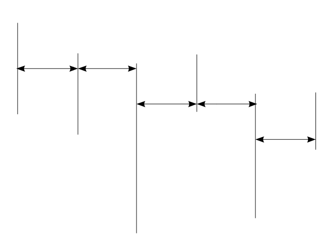

Fig. 4. The positioning accuracy

Fig. 5. The repeatability of the system

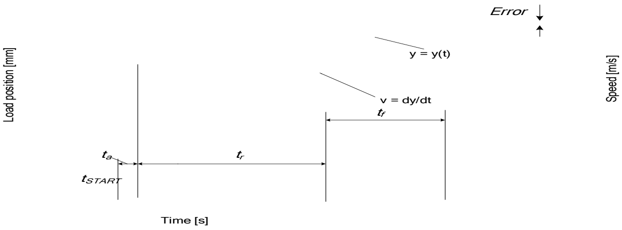

Fig. 6. The dynamic behavior of the positioning system

Figure 6 shows the dynamic performances of the positioning system. Starting from the initial position y_i=10 mm, the target position y_f=390 mm was programmed. The diagrams y=y(t) and v=dy/dt were computed.

4. CONCLUSIONS

The performances of the proportional pneumatic equipment, the manufacturing process quality of the mechanical structure and the purity of the used working fluid determine the position accuracy of the mechatronic unit. The tests performed with the presented positioning system revealed that it is possible to obtain a range of positioning accuracy about ± 0.3 mm.

The future researches will be focused on: reducing the sizes of the developed valve; reducing its final cost; finding new methods to minimize the valve hysteresis; increasing the positioning accuracy of the pneumatic units using this valve, until errors of hundreds of mm can be reached.

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