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A NEW PNEUMATIC CONTROL SYSTEM USING MULTIPLEX PNEUMATIC TRANSMISSION

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ABSTRACT

The purpose of this research is simplifying and downsizing of pneumatic system consisting of many pneumatic actuators. For this purpose a new method of multiplex pneumatic transmission for multi-pneumatic servo system is proposed. The pneumatic valve for this system has a simple structure consisting of two vibrators supported by springs. The working principle of the valve is based on vibrator resonance caused by multiplex pneumatic vibration in air supply line and this makes the valve work as an ON/OFF valve without electric wire or independent pneumatic tubes. Valve control needs superimposed only an air supply tube for its independent control, making this pneumatic system suitable for the system having many degrees of freedom.
Two prototype valves have been developed to confirm the basic function and adapted to the pneumatic system consisting of two pneumatic cylinders. The prototype valve has been designed based on the result of a dynamic simulation and it was confirmed by basic experiments. In the experiment, the independent control for two pneumatic cylinders with prototype valves has been successfully realized.

KEY WORDS

Actuator, Pneumatic valve, Resonance

INTRODUCTION

A pneumatic actuator has several advantages, which are lightweight, low cost, high compliance, and reliability to humans. However, the system using pneumatic actuators is complicated in general with a compressor, control valves, and air tubes. Researches for downsizing of compressor and control valve have been actively studied [1]-[3]. Solving a lot of control wires to control valves is also studied [4].
The purpose of this research is simplifying pneumatic system having many degrees of freedom. For this purpose we have proposed a new method of multiplex pneumatic transmission for the multi-pneumatic servo system [5]. The pneumatic valve for this system consists of two vibrators and springs. The working principle of the valve is based on vibrator resonance caused by multiplex pneumatic vibration. This valve works as an ON/OFF valve without electric wire but works just through one air supply line. This pneumatic system using the valve realizes independent control of valves with only air tubes. It is effective for the pneumatic system having many degrees of freedom.
The basic working has been confirmed by dynamic simulation and vibration experiment using experimental

model [6]. The experimental model was designed based in the simulation and structure analysis. In this paper, a pneumatic experiment using the experimental model is described.

WORKING

Figure 1 shows the proposed system. This system is configured with multiplex pneumatic transmission, which consists of a PC, and a pressure servo valve. Each proposed valve has a deferent resonant frequency. This valve works as an ON/OFF valve by multiplex pneumatic transmission.

For example, when the actuator 1 is requested to be driven it can be driven by superimposing air vibration of its resonant frequency in the air supply line. The actuator 2 is driven in the same way. When both actuators 1 and 2 will be needed for drive it can be achieved with an air vibration combined with two frequencies.

The representative advantages of this system are follows;

- It can drive many independently actuator without electric wires.
- The structure of the valve is simple.
- This valve in the system can be configured only air tube to actuator.

This system is effective to the system having many degrees of freedom.

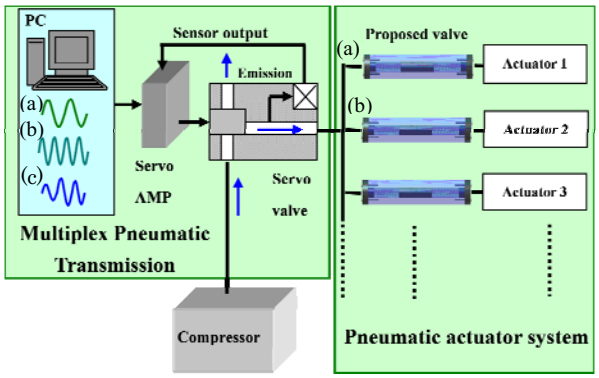


Figure 1 Multiplex pneumatic system

EXPERIMENTS

Valve

Figure 2 shows an outer view of the experimental model for pneumatic valve used in this system. This valve is configured with two vibrators and rubber bellows and linear guide. The rubber bellows is designed using FEM to realize the desired spring constant. The resonant frequency is obtained using the mass and spring constant as shown in Eq. (1).

$$\omega_n = \sqrt{\frac{k}{m}} \tag{1}$$

Figure 3 shows the working principle of the experimental model. These motions of the vibrators are caused by multiplex pneumatic vibration transmitted from port A. The supply air to the actuator flows through port B to port C. When the driving frequency of pressure from port A is at non-resonance frequency two vibrators move keeping their contact. Thus the pressure from port B is supplied to actuator through port C. When the driving frequency is resonance frequency two vibrators move in different ways to separate. The pressure of Pl_2 from gap between left vibrator and L-shaped angle is increased. The supply pressure to actuator is decreased. In this way model works as an exhaust valve.

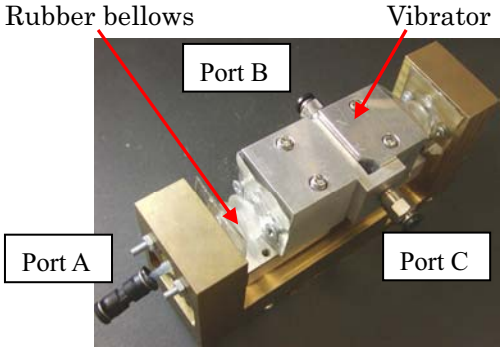


Figure 2 Experimental model

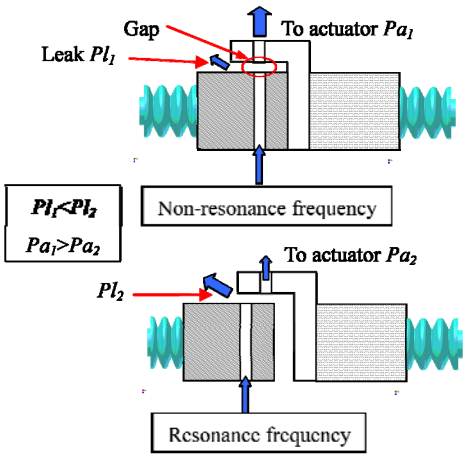


Figure 3 Principle of experimental model

Experimental system

Figure 4 shows the experimental system using two experimental valves. Table 1 shows the parameters of the experimental valves. The real values of resonant frequency are measured through basic experiment.

The experiment is made for the pneumatic system for driving two double-acting cylinders. The supply pressure to double-acting cylinder is about 0.1 [MPa]. Two experiment models have deferent resonant frequency each other. One vibrator in made of stainless steel and the other is made of aluminum. The constant pressure of 50 [kPa] as back forces is supplied to right room of double-acting cylinder.
The input signal to pressure servo system is controlled by a PC and a servo valve. Two experiment models are controlled independently with following four modes;

- [mode A] for driving cylinder A
- [mode B] for driving cylinder B
- [mode C] for non-driving both cylinders
- [mode D] for driving both cylinders

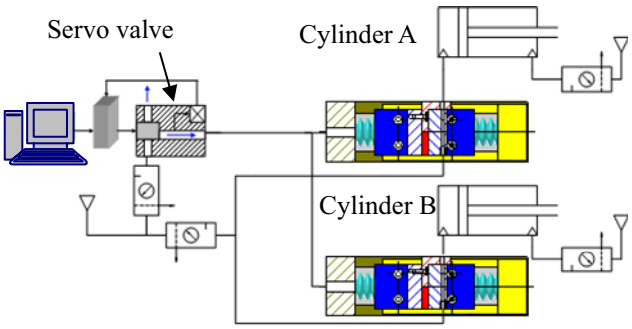


Figure 4 Experiment system

Table 1 Parameters of designed valves

		Valve 1	Valve 2
Vibrator	Material	stainless	aluminum
	Mass	226 [g]	76 [g]
Bellows	Spring constant	0.175 [N/mm]	
Resonance frequency	Theoretical value	4.4 [Hz]	7.6 [Hz]
	Real value	6.2 [Hz]	11.8 [Hz]

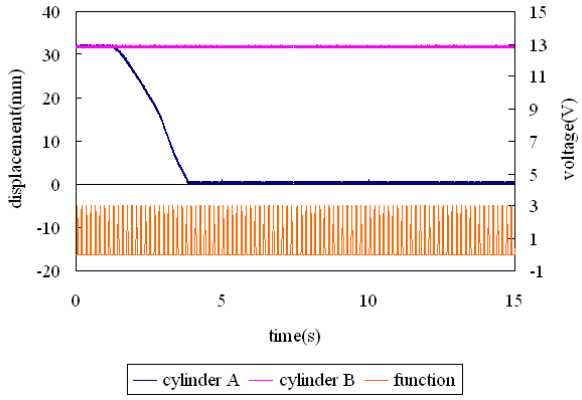
Results
Figures 5 show experimental results for driving two pneumatic cylinders. Equations (2), (3), and (4) show input pneumatic signals and motions of cylinders for modes A, B, and D respectively.

$$f_A = 7.0 \times \sin(2\pi \times 6.4 \times t) - 4.0 \quad (2)$$

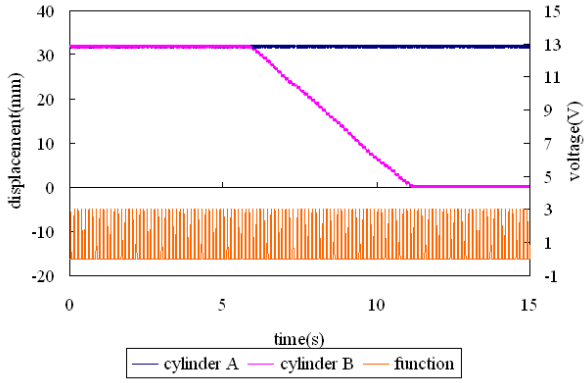
$$f_B = 7.0 \times \sin(2\pi \times 8.2 \times t) - 4.0 \quad (3)$$

$$f_D = 3.5 \times \{\sin(2\pi \times 8.2 \times t) + \sin(2\pi \times 6.4 \times t)\} - 3.0 \quad (4)$$

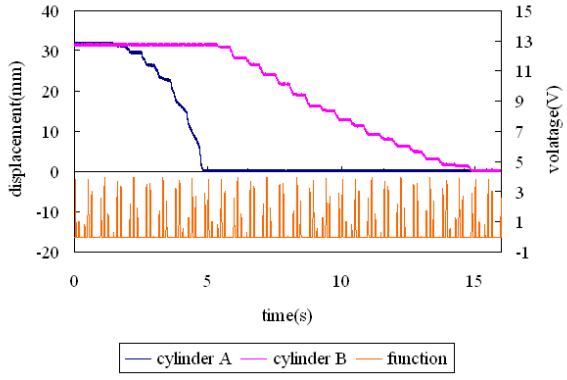
The experiment shows that the system works successfully: the cylinder A works independently for modes A and B, as shown in Figures 5 (a) and (b). Both cylinders work at the same time as shown in Figure 5 (c) for mode D. It shows a great potential of new pneumatic control system.
From the experiment, the response of pneumatic cylinder was confirmed each. The response speed is deferent for mode A and mode B as found in Figure 5 (c). This results from deference of vibration amplitude of the valves.



(a) mode A



(b) mode B



(c) mode D

Figures 5 Experimental results

CONCLUSION

A new method of multiplex -pneumatic transmission has been proposed. This method realized great simplification of pneumatic system consisting of many actuators. A control valve for this pneumatic system is driven only through an air tube without electric wires. In this paper, experimental models was developed and adapted to pneumatic system. In this experiment, the independent driving of two pneumatic cylinders is realized. The principle of the proposed system was shown in this experiment.

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