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Piezoelectric Transducer Design for Particle Excitation Hydraulic Control Valve

微粒子励振型油圧制御弁のための圧電トランスデューサの設計

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1. Introduction

Conventional small hydraulic servo valves have some disadvantages such as a complex structure, waste of hydraulic energy, and the necessity of high contamination control. That is because the valves have a two stages and modulate spool position by the amplified force of the motor. As a way to solve these disadvantages, we study to apply a particle excitation flow control valve to hydraulics.[1,2] The valve features small size, simple structure, and flow-controllability including on/off control. It was confirmed that the valve can control the flow rate, when silicone oil is used as the working fluid.[2] However, to open the valve under high pressure and high viscosity needs a large force. For pneumatic systems, therefore, some methods were proposed in order to decrease the opening force of valves using vibration owing to changing the direction of the force to open the valve.[3,4] In this paper, we design a new hydraulic valve which is driven by perpendicular force to a direction of flow. In addition, we describe the characteristics of the prototype valve.

2. Working principle

Figure 1 shows the working principle of the previous model and the new model.[2] The particle excitation valve consists of an orifice plate, a piezoelectric vibrator, and a particle. In non-driving state, the particle which is carried onto the orifice by fluidic force seals the orifice. In order to move the particle from the orifice, the vibration which is excited by the piezoelectric vibrator at the resonance frequency is applied to the particle. Thereby the particle gains the inertial force and leaves the orifice. In Fig. 1(a), the direction of the inertial force shows the opposite direction of the force by pressure. Therefore, the inertial force needs larger force than the force by pressure. In contrast, in Fig. 1(b), the inertial force shows the horizontal direction to the force by pressure. As a result, it is expected that the particle could be moved by the small force.

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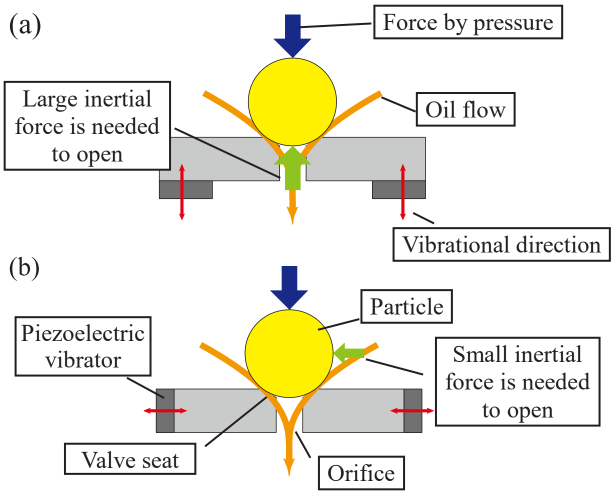

Fig. 1 Working principle of the particle excitation control valves: (a) previous model and (b) new model.

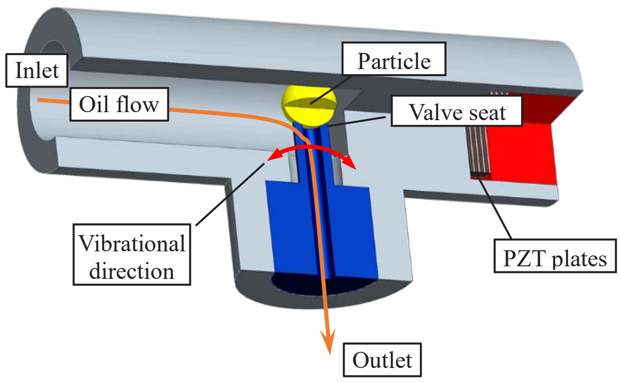

Fig. 2 Structure of proposed valve.

3. Design and analysis

Figure 2 illustrates the structure of the proposed valve based on the concept mentioned in Fig. 1(b). The prototype valve was designed using a modal analysis. The analytical result of the proposed valve is shown in **Fig. 3**. In this analysis, four stacked lead zirconate titanate (PZT) plates were used as an actuator. It was verified that the valve seat resonates the horizontal direction in the figure. The fabricated prototype valve which is based on the analytical results is shown in **Fig. 4**.

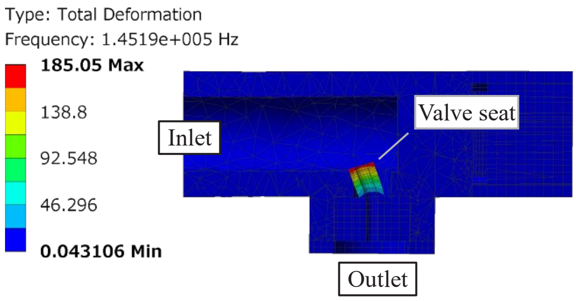

Fig. 3 Analytical result of vibration mode by using finite element method.

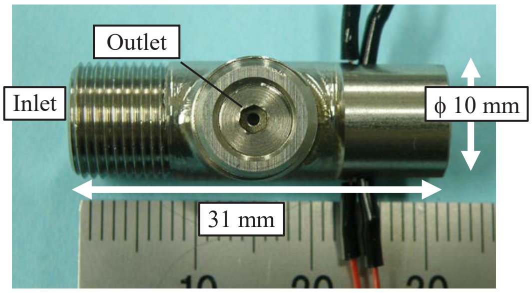

Fig. 4 Photograph of prototype valve.

4. Experiments

The characteristics of the transducer were evaluated. The piezoelectric vibrator stacked with four PZT plates was used in the evaluation. First, the relationship between admittance and frequency was measured. The measurement result is shown in **Fig. 5**. As shown in this figure, the resonance frequency was 149 kHz. The horizontal vibrational velocity at the valve seat was also measured with a laser Doppler vibrometer. The measurement result is shown in **Fig. 6**. The maximum vibrational velocity was 235 mm/s at 148 kHz.

In order to evaluate the characteristics of the prototype valve, the minimum driving voltage to open the valve was measured in pneumatic system and hydraulic system. The piezoelectric vibrator stacked with eight PZT plates was used. Silicone oil (kinematic viscosity: 1 mm^2/s) was used as the working fluid in the hydraulic system. The experimental result is shown in **Fig. 7**. The minimum driving voltages to open the valve in pneumatics and hydraulics were 35 $V_{p\text{-}p}$ and 44 $V_{p\text{-}p}$, respectively, when the impressed pressure was 0.5 MPa. The driving frequencies were 153.5 kHz and 77.5 kHz in pneumatics and hydraulics, respectively.

5. Conclusion

In this paper, we introduced the new design of the particle excitation control valve and its results of fundamental experiments. We have succeeded in driving the valve at 0.5 MPa. This fundamental evaluations indicated the possibility of the proposed valve.

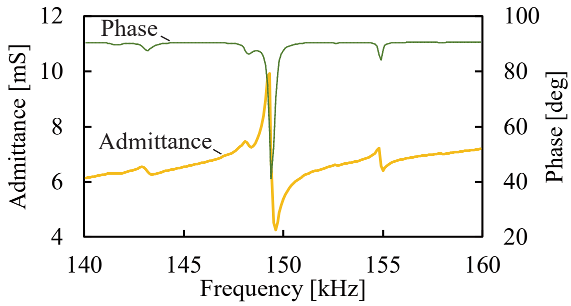

Fig. 5 Relationship between admittance of the valve and frequency.

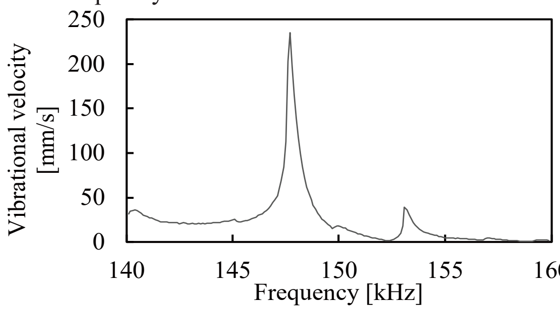

Fig. 6 Relationship between horizontal vibrational velocity at the tip of the valve seat and frequency, when applied voltage was 10 $V_{p\text{-}p}$.

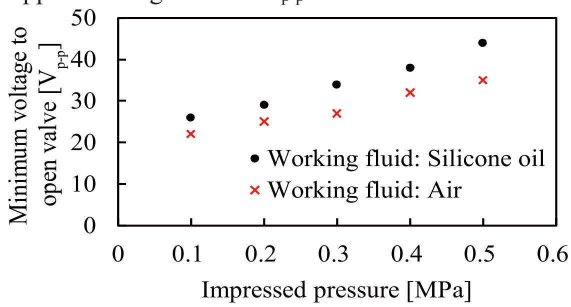

Fig. 7 Relationship between minimum driving voltage to open valve and impressed pressure.

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References

1. D. Hirooka, K. Suzumori, and T. Kanda: Sens. Actuators A **171** (2011) 283.
2. T. Ukida, K. Suzumori, H. Nabae, T. Kanda, and S. Ofuji: Proc. JSME Conf. Robotics and Mechatronics, (2016), 1P1-09b7 [in Japanese].
3. T. Akagi, S. Dohta, and S. Katayama: JFPS Int. J. Fluid Power Syst. **2** (2009) 45.
4. D. Hirooka, T. Yamaguchi, N. Furushiro, K. Suzumori, and T. Kanda: Proc. JSME Conf. Robotics and Mechatronics, (2014), 2A1-Q04 [in Japanese].