DESIGN OF PIEZOELECTRIC HYDRAULIC PUMP BASED ON MEMS VALVE

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Summary Morphing aircrafts adapt to different flight conditions and expand flight envelope by changing the wing parameters such as wing area, aspect ratio, backswept etc. However the additional weight of the morphing system is one of the most important limit factors. High-performance low-weight actuators would solve this problem as an important way. In this paper, a novel piezoelectric hydraulic pump is designed and manufactured. Since the high frequency response of the pump and small liquid output in each working cycle, a MEMS processed micro-valve structure is proposed and designed in this paper. The micro-valve is fabricated by MEMS technology and works as the check valve of the pump. Preliminary experimental study of the piezoelectric pump prototype is conducted, which shows the output pressures is up to 20 kPa.

PIEZOELECTRIC HYDRAULIC PUMPS DESIGN

Traditional hydraulic pumps use the electric motor as drive component, which have the strongpoint of large output force and large output power. Piezoelectric hydraulic pumps use piezoelectric stack as drive component and inherit the advantage of the traditional hydraulic pumps[1]. Besides, they are simple and reliable, and have large ratio of output force to weight and large ratio of output power to weight. Therefore, piezoelectric hydraulic pumps have better application prospect in micro-pump[2-4].

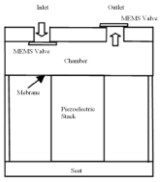

Fig.1 Piezoelectric Pump Structure Design

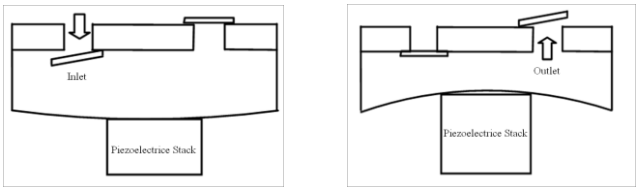

Fig.2 Piezoelectric Pump Principle

Piezoelectric hydraulic pumps principle

Piezoelectric pump is made up of piezoelectric stack, seat, membrane, chamber, MEMS valves, inlet and outlet, shown in figuer1. Figuer2 shows the principle of the pumps. When the piezoelectric stack elongates, chamber volume reduce and internal pressure increase. Because of the pressure differential effect, the outlet valve opens and the liquid outflows; When the piezoelectric stack shortens, chamber volume increases and internal pressure decreases, and the inlet valve opens and the liquid flow into the chamber. With constant elongation-recovery, the liquid can serve as drive source.

MEMS VALVE DESIGN AND FABRICATION

MEMS valve principle

MEMS valve is controlled by the pressure differential between both sides of the valve (figure3): When the pressure differential is greater than the critical pressure, the fluid flows out through the stopped clearance, the valve is in the opening state; When the pressure differential is less than the critical pressure, the valve contacts with the seat closely, the channel is blocked, the valve is in the closing state.

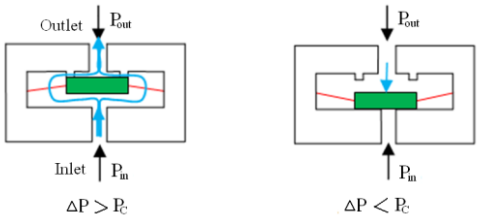

Fig.3 Opening and Closing States of Valve

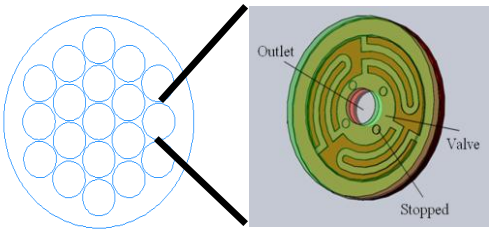

Fig.4 MEMS Valve Structure

MEMS valve design

MEMS valve array contains 19 valve units, which consists of inlet, valve, stopped and outlet (as shown in figure 4 shows). Finite element analysis of the valve is done through ANSYS software. The first mode of the valve is normal

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vibration. Within the designed frequency, there are no skewing and torsion for the valve (figure 5). Figure 6 shows the maximum stress is appeared in the corner of the valve arm while opening, it increases linearly with the valve's thickness.

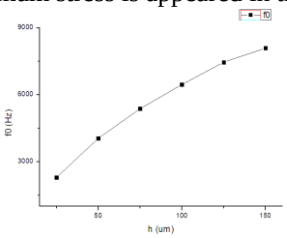

Fig.5 MEMS Valve Unit First Natural Frequency

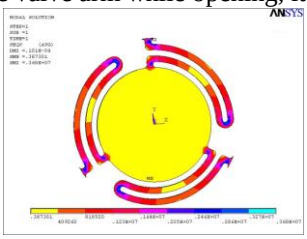

Fig.6 The Stress Distribution of Valve Unit under Opening

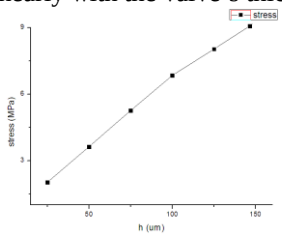

Fig.7 Cure of the Largest Stress Thickness of the Valve Unit under Opening

MEMS valve fabrication

MEMS valve is made by lithography process. All structures are composed by SU-8. The whole processing is as follows:
(a)Manufacture inlet layer on the silicon substrate using SU-8;
(b)Make sacrificial layer on the inlet layer with AR photoresist;
(c)Then photoetch the valve layer using SU-8;
(d)Create one more sacrificial layer;
(e)Produce stopped layer with SU-8;
(f)Fabricate outlet layer using SU-8;
(g)All AR photoresist molds are removed by using AR remover;
(h) Finally, make structure from silicon substrate by soaking in NaOH saturated solution.

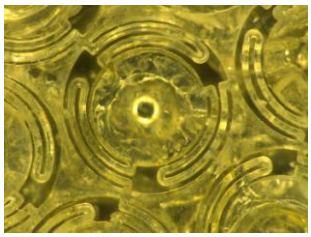

Fig.8 MEMS Valve Structure

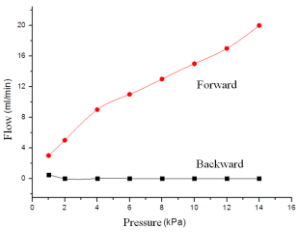

Fig.9 MEMS Valve Flow Characteristic

PIEZOELECTRIC HYDRAULIC PUMPS EXPERIMENT

A piezoelectric pump prototype is manufactured. Then the output press and output capacity are tested. In the low frequency conditions, there is a linear relationship between the flow and input frequency as shown in figure 10. The cure of the output flow under 10Hz working frequency is shown in figure 11, which increase with the input voltage. The output flow of pump decreases with the increasing of input voltage, and the maximum output pressure of the prototype is up to 20 kPa (as shown in figure 12).

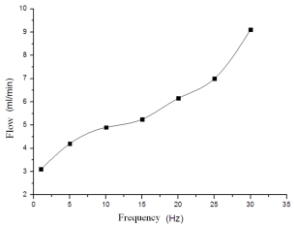

Fig.10 The output flow under different frequencies

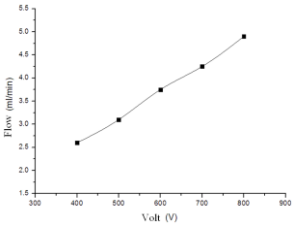

Fig.11 The output flow under different input volts

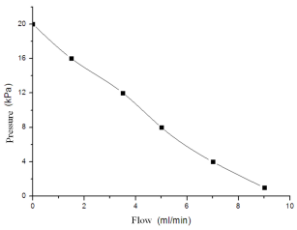

Fig.12 Cure of flow- pressure

CONCLUSIONS

In this paper, a novel piezoelectric hydraulic pump based on MEMS valve is designed and Manufactured. The MEMS valve has good performances of forward flow and reverse closure. The maximum output pressure of piezoelectric pump prototype is 20 kPa, and the output capacity is 9.2 ml/min under 30 Hz.

References

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[4] Conal O'Neill, John Burchfield, Kinetic Ceramics Piezoelectric Hydraulic Pumps, Industrial and Commercial Applications of Smart Structures Technologies, Proceedings of SPIE, 6527：65270I-1~14, 2007.