Development of Tube Type Valve-less Micropump with Ring Type PZT Actuator

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Abstract

A new type of valve-less micropump which consists of a tube and piezoelectric rings located at equal intervals on the tube has been proposed. The liquidity for the micropump was confirmed (a few percent increased and decreased, compared with the static state), however, since the liquidity is not enough large. Therefore, highly efficient liquidity micropump is needed. In this research, we focused on the progressive wave based on the principle of the fluid transportation to improve the liquidity and control the liquidity accurately. First of all, the progressive wave theoretical model for the fluid transportation was constructed. Next, the significant parameter in the model for improvement of liquidity was searched. As the result, the liquidity was changed by the difference of the number of PZT on a tube experimentally. It was suggested that the amplitude to change by the number of PZT is the most significant factor in the model. Moreover, it was confirmed experimentally that the amplitude of a large progressive wave can be obtained by selecting the best PZT interval on a tube and flow velocity was improved.

1 Introduction

Micro Electro Mechanical Systems (MEMS) has been famous technology, because the development of micropump for drug injection in an amount in micro liter and for blood extraction in a sub micro liter can be achieved by the technique[1],[2]. For example, the piezoelectric pump is well known to control the flow rate of liquid precisely. Therefore, the pump is adopted for μ-TAS[3]. However, channels for liquid flow can design only on a glass or plastic board so that there is a problem to limit in the miniaturization for the pump with a complex channels design[4].

In order to produce a new type of micropump smaller than the conventional pump, therefore, the valve-less micropump combined with a tube and ring type PZT elements mounted equally on the surface of the silicone tube was proposed. The progressive waves in the tube are generated by the vibration of those PZT on the tube by the AC frequency. The flow liquidity by the micropump was demonstrated that the flow rates based on the static state 1 ml/sec were increased 5.91 % and decreased 1.79 % at the voltage of 80 Vpp offset to the inner direction when evaluation fluid was water[5]. Here, the liquid flow through the tube in the static state occurs by the atmosphere pressure (0.1013 MPa). Therefore, when the flow rate is increased, the pressure is increased approximately 1 % by the micropump to compare with the atmosphere pressure. However, the change of flow rate is not enough large. In this study, we focused on the progressive waves regarding the fluid transportation principle to be able to improve the liquidity and control the flow speed accurately. Moreover, the progressive wave theoretical model which was the principle of the fluid transportation is constructed.

2 Transportation principle of fluid in tube

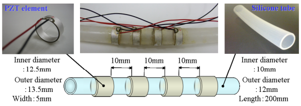
In this study, the micropump consists of a silicone tube and ring type PZT elements, which is called the valve-less tube type micropump. The four to eight PZT elements are located away to equal distance, shown in Fig. 1. The PZT elements called C-9(d_{33}=718 pm/V)) produced by the Fuji Ceramics Company were used. The size of the PZT element was 12.5 mm in the inner diameter, 13.5 mm in the outer diameter, and 5mm in width, respectively. The turn back electrode was adopted not to obstruct the displacement of the radial direction. Next, the size of the flexible silicone tube was 10 mm in the inner diameter and 12 mm in the outer diameter. The PZT element and the silicone tube are fixed with commercial based glue.

When it applied AC voltages to the ring type PZT elements, the breath vibrations are generated from the ring type PZT elements. The stationary waves with different vibrations are generated inside of the wall of the silicone tube by those vibrations. Therefore, the progressive waves combined with those stationary waves with vibrations with different phase are transmitted to the liquid in the tube. The fluid is moved and transported from an initial position by the progressive wave. Here, the ring type PZT micropump fulfilled by water is located on a stable fixture. Then water flows from the water storage tank connected to the micropump under the atmosphere pressure (0.1013 MPa). Amount of water flows from another edge of the pump is measured by micro balance. The amount of water flow and time were measured five times, and the flow rates were calculated. Here, a flow rate is defined as a flow velocity. The flow rate was evaluated by comparing the flow velocity in the case of static state (no applied voltage) and in the case of changing voltage applied to PZT elements.

In order to improve the flow rate and establish the appropriate control, the progressive wave theoretical model based on the principle for the fluid transportation should be constructed. Here, the progressive wave in case of PZT numbers "m" in a micropump is considered. In the conditions to generate the progressive wave in the fluid, (1) same AC frequencies and amplitudes of the stationary waves from Ch1 and Ch2, (2) the 90 degrees phase variation for stationary wave from 2Ch against Ch1, and (3) the even PZT numbers and same pieces from the center of the pump ($m=4i+4$(i=0, 1, 2…)) must be satisfied. The expression (1) in Fig.1 shows the amplitude for the progressive wave. According to expression (1), it is clear that the larger numbers "m" is to be larger amplitude of the progressive waves.

3 Experiment of flow function evaluation

In this chapter, flow rates of the valve-less tube type micropump with PZT actuator are evaluated with changing "m" described in expression (1) under the experimental conditions shown in Table 1. Fig.2 shows the flow rate changes as a function of numbers for PZT on a tube under the condition shown in Table 1. According to Fig.2, the flow rate was increased when increase of "m", since the amount of amplitude for the progressive wave in the theoretical model is large when increase of "m". Therefore, it is clear by both the theoretical and the experimental methods that an increase in the amplitude of the progressive wave in expression (1) is a significant factor of the liquidity improvement. And also, it is assumed that the changeable parameters in expression (1) such as wave numbers (consists of mechanical property such as a young's modulus for tube) can effect amplitude to improve flow rate.



$$y(t) = 2\sqrt{2}a\sin(kl + \frac{3}{4}\pi)\sum_{i=0}^{i}\cos\{(2i+1)kl + \omega t\} \quad \cdots (1)$$

i : Installation interval, a : Amplitude,
k : Wave number, ω: Angular frequency,
t : Time, m: Number of PZT

Figure 1: Schematic diagram of micropump.

Table1: Experimental conditions for liquidity verification.

Number of PZT element	4, 8
Evaluation fluid	Pure water
Flow rate as a static state	1.00ml/sec
AC frequency	Ch1, Ch2: 3.0kHz
AC power	40Vpp, 80Vpp

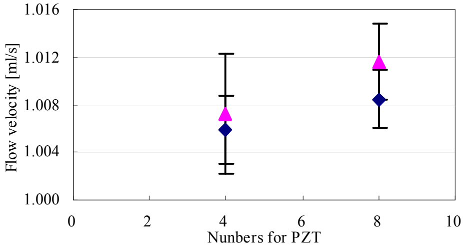


Figure 2: Flow velocity change as a function of numbers for PZT on a tube.

4 Conclusion

In order to recognize the liquidity for the valve-less PZT micropump, the liquidity as a flow velocity is evaluated by changing numbers of PZT as a parameter in the progressive wave theoretical model. The following knowledge was obtained.

- The amplitude in the progressive wave is the most significant factor to improve the liquidity.
- PZT numbers "*m*" on a tube is a controllable parameter for the micropump liquidity.

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