3Pa4-2

Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 373-374
8-10 November, 2011

A Study on Micro Droplet Generation by Using Ultrasonic Torsional Transducer

超音波ねじり振動子による微小液滴生成に関する研究

Yusuke Kiyama[1†], Yoshiyuki Tominaga[1], Takefumi Kanda[1], Koichi Suzumori[1], Norihisa Seno[1] ([1]Okayama Univ.)
木山 雄介 [1†], 富永 宜幸 [1], 神田 岳文 [1], 鈴森 康一 [1], 妹尾 典久 [1] ([1]岡山大学)

1. Introduction

In fields such as electronic materials, cosmetics productions and medical science, monodisperse droplets have been an important subject[1, 2]. In this study, we have designed an ultrasonic torsional transducer to apply a high pressure to use high viscosity liquids and generated micro droplets in the air by using this transducer[3, 4]. In addition, we have evaluated the condition of the driving frequency and the ejection speed of droplets when we generated droplets.

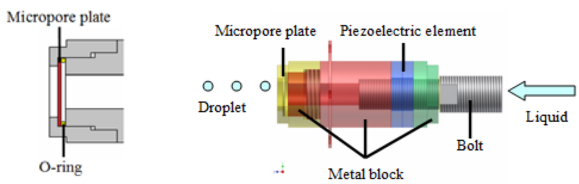
2. Structure

Schema of the ultrasonic torsional transducer is shown in **Fig. 1**. This transducer consists of circumferentially polarized piezoelectric elements, a micropore plate, metal blocks and a bolt.

The micropore plate attached at the tip of the transducer vibrates in vertical direction against the flow of liquid. When the micropore plate vibrates, droplets are generated regularly by ruffling liquid surface.

We simulated a vibrational mode of the transducer by using a finite element method. The simulation result is shown in **Fig. 2**. From this result, we confirmed the torsional vibration mode and the resonance frequency of the torsional vibration mode at 37 kHz. The fabricated ultrasonic torsional transducer based on this analytical result is shown in **Fig. 3**. The diameter of this transducer is 24mm and the length is 81mm. The transducer is fixed at the flange which is placed at the node of the vibration.

The SEM photograph of micropore is shown in **Fig. 4(a)** and its cross-sectional view is shown in **Fig. 4(b)**. The micropore plate is made of stainless steel, the diameter of the micropore plate is 16mm, the thickness is 150μm and it places 5mm distance from the center. As shown in Fig. 4(b), the micropore has a taper. The diameter of the larger aperture is 128μm and that of the smaller aperture is 16μm. The liquid flow direction is from the larger aperture to the smaller aperture.



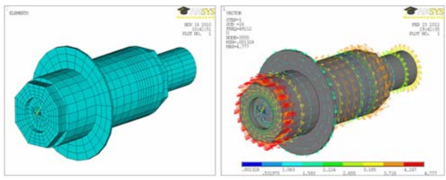
(a) Close-up view of tip (b) Structure of transducer
Fig. 1 Schema of ultrasonic torsional transducer

kiyama10@act.sys.okayama-u.ac.jp

3. Droplet generation in the air

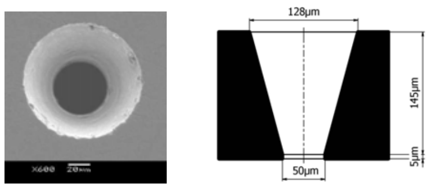
The droplet generation in the air has examined experimentally by using the fabricated transducer. The experimental setup for the droplet generation is shown in **Fig. 5**. Pressured liquid is supplied to the transducer by a constant pressure pomp. Discharged droplets are observed by using a high-speed camera and a microscope. The supplied liquid was pure water.

The photographs of observed droplets when the vibration amplitude of the micropore was 0, 0.14 and 0.25$\mu m_{p\text{-}p}$ are shown in **Fig. 6**. The applied



(a) Model of analysis (b) Result of modal analysis
Fig. 2 FEM analysis of ultrasonic torsional transducer

Fig. 3 Photograph of fabricated ultrasonic torsional transducer



(a) SEM photograph of micropore (b) Cross-sectional view of micropore
Fig. 4 Schema of micropore plate

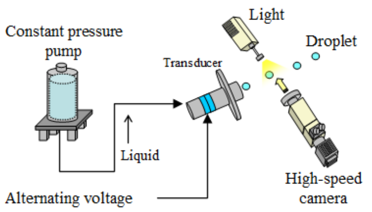


Fig. 5 Experimental setup for droplet generation

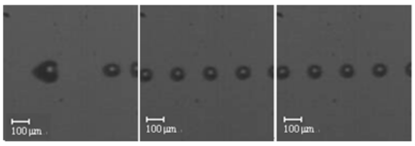


Fig. 6 Photographs of droplets when the vibration amplitude was 0, 0.14 and 0.25$\mu m_{p\text{-}p}$ (left to right)

Table 1 Relationship between vibration amplitude and droplet diameter

Vibration amplitude [$\mu m_{p\text{-}p}$]	0	0.14	0.25
Average diameter [μm]	94.0	86.2	85.3
Standard deviation	18.3	0.93	0.89

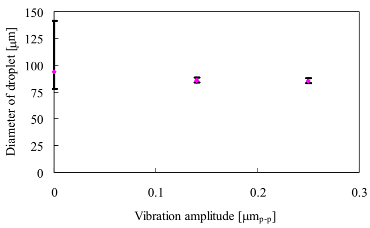


Fig. 7 Relationship between vibration amplitude and droplet diameter when the applied pressure was 0.05MPa

Table 2 Relationship between driving frequency and droplet diameter

Driving frequency [kHz]	0	21	40	62	77
Vibration amplitude [$nm_{p\text{-}p}$]	0	27.6	28.1	4.23	11.9
Average diameter [μm]	78.2	80.3	99.5	84.7	79.1
Standard deviation	26.2	15.1	4.44	0.84	7.34

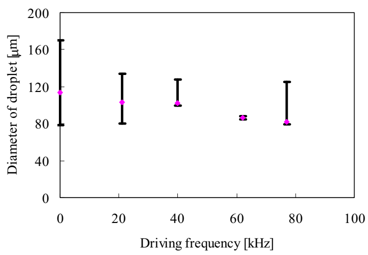


Fig. 8 Relationship between driving frequency and droplet diameter when the applied pressure was 0.20MPa

pressure was 0.05MPa. The relationship between the vibration amplitude and the droplet diameter is shown in **Table 1** and **Fig. 7**. From this result, we confirmed that we obtained micro and uniform droplets by oscillating the micropore.

Additionally, we have evaluated the condition of the driving frequency and the applied pressure when we generated droplets. The relationship between the driving frequency and the droplet diameter when the applied pressure was 0.20MPa is shown in **Table 2** and **Fig. 8**. From this result, we

Table 3 Relationship between applied pressure, driving frequency and droplet diameter

Applied pressure [MPa]	0.05	0.15	0.20	0.25
Driving frequency [kHz]	21	40	62	77
Vibration amplitude [$nm_{p\text{-}p}$]	27.6	28.1	4.23	11.9
Average diameter [μm]	100.3	97.0	86.5	83.0
Standard deviation	0.60	0.95	0.84	0.67

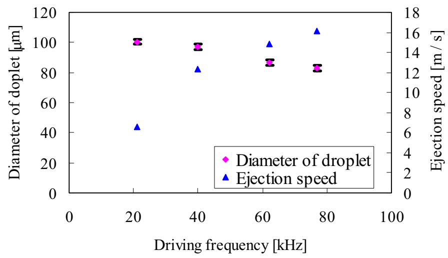


Fig. 9 Relationship between driving frequency, droplet diameter and ejection speed when the applied pressure was 0.05, 0.15, 0.20 and 0.25MPa

confirmed that we obtained droplets which had small and uniform diameters when the transducer was driven by the frequency which was suitable for the applied pressure. The suitable applied pressure was decided based on the flow rate.

Next, we examined the frequency which was suitable for the applied pressure when the applied pressure was changing. The relationship between the driving frequency, the applied pressure and the droplet diameter is shown in **Table 3** and **Fig. 9**. Additionally, the ejection speed of the droplet which ejected from the micropore is shown in Fig. 9. From this result, we confirmed that we obtained droplets which had small and uniform diameters at various frequencies. We confirmed that the driving frequency which was suitable for the flow rate was larger as the ejection rate was faster when the applied pressure was larger.

4. Conclusion

In the paper, we have evaluated the condition of the droplet generation by using the ultrasonic torsional transducer experimentally. Therefore, we have realized that the driving frequency had the suitable flow rate.

References

1. T. Shimoda, K. Morii, S. Seki and H. Kiguchi: MRS Bull. **28** (2003) 821.
2. S. E. Burns, P. Cain, J. Mills, J. Wang and H. Srringhaus: MRS Bull. **28** (2003) 829.
3. T. Harada, N. Ishikawa, T. Kanda, K. Suzumori, Y. Yamada and K. Sotowa: Sens. Actuators A. **155** (2009) 168.
4. Y. Tominaga, T. Harada, T. Kanda and Y. Yamada: *ACTUATOR* (Bremen Exhibition and Congress Center, Germany, 2010) p. 1029.