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Removal of liquid in an elongated pore by very high-intensity aerial ultrasonic waves
極強力空中超音波による微小な孔内に浸入した液体の除去

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1. Introduction

We experimentally verified the method of using the radiation force of the high-intensity aerial ultrasonic waves at a frequency of 20 kHz to remove a liquid that entered a long pore. In previous studies[1)-3)], the liquid in an elongated pore of 2.0 mm diameter could be removed by this method. However, it was not possible to remove the liquid in elongated pores of 1.5 mm or less in diameter because the maximum sound pressure which could be generated by the conventional sound source was 5 kPa. On the other hand, recently, we have realized the generation of the very high-intensity aerial ultrasonic waves by a new method.In this report, we attempted to remove the liquid in the smaller elongated pore by using the new ultrasonic source.

2. Experimental equipment

Fig.1 shows a schematic view of the equipment used in our experiments. A new point converging ultrasonic source of strip mode vibrating plate[4)] was used to produce the very high-intensity aerial ultrasonic waves. **Fig.2** shows the relationship between the sound pressure at the convergence point O and the power supplied to the sound source. The sound pressure at the convergence point is approximately 14 kPa at the input power of 50 W, as shown the figure. The sound pressure is more than twice stronger than that of the conventional sound source. We couldn't directly measure the sound pressure at the input power of 50 to 100 W, because those values exceeded the measurable limit of 1/8- inch condenser microphone. Therefore, we estimated sound pressure from the result of fig.2. The sample used for each experiment was a straight pore having a cross section rectangular with open ends made of acrylic. **Table I**. gives the size of the pore. As the liquid in the pore, we used pure water, in which a trace of a white water paint was mixed to observe the liquid more easily. The behavior of the liquid irradiated with the ultrasonic waves was observed in detail by using a digital microscope with a high-speed camera.

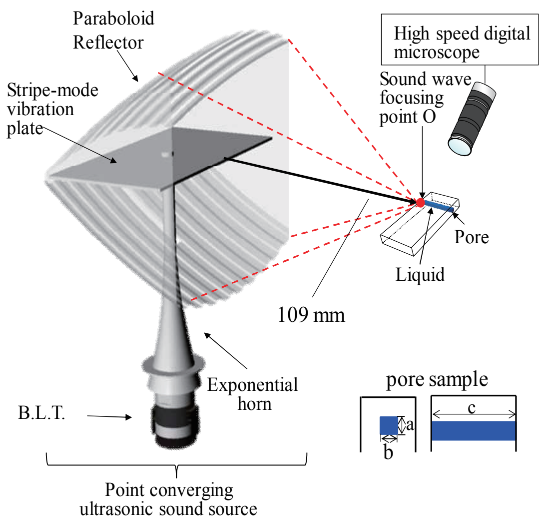

Fig.1 Schematic of experiment

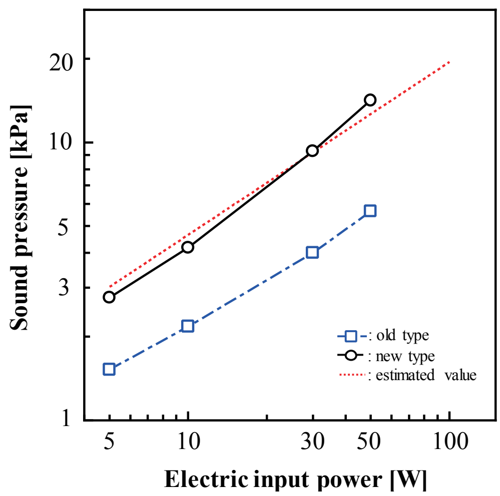

Fig.2 Relationship between the sound pressure at the convergence point O and electric input power

Table I. Detail of samples

Sample	I	II	III	IV	V
Length a,b [mm]	0.6	0.8	1.0	1.5	2.0
Length c [mm]	20	20	20	20	20

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3. Effect of ultrasonic waves on removal of liquid from a pore

As shown in Fig.1, the behavior of the liquid irradiated with the ultrasonic waves was observed microscope with a high-speed camera. As an example, **Fig.3** shows the observation result of the smallest sample I . Fig.3 (a) indicates the liquid in the pore without ultrasonic irradiation. Fig.3 (b) indicates almost of all the liquid drops were pressed out of the pore with ultrasonic irradiation. In addition, it was observed that almost all the liquid drops were pressed out of the smallest pore of 80mm length.

Next, it was measured the time required to remove the liquid from the pore by using the digital microscope, for each sample. **Fig.4** shows the relationship between the time required to remove liquid and the sound pressure of the irradiated sound wave. Here, the time required to remove the liquid from the pore is defined as the time between when the irradiation of the ultrasonic waves starts and when almost all the liquid in the pore removed from the pore. As shown in the figure, the time required to remove the liquid was shorter with the increase of the sound pressure. In addition, the time required to remove was longer with smaller of the cross section of the pore.

The liquid removal rate with respect to the irradiation intensity of sound waves was investigated. The liquid removal rate was determined from the weight ratio between the liquid in the pore before and after the irradiation of the liquid with the ultrasonic waves. **Fig.5** shows the relationship between the liquid removal rate and the sound pressure. As a shown figure, the liquid removal rate was increased with the increased of the sound pressure. We couldn't measure the weight of residual liquid when the liquid removal rate was over 95%, because that was less than the smallest measured value with an electronic balance.

4. Conclusion

We experimentally verified the method of using the radiation force of the very high-intensity aerial ultrasonic waves at the frequency of 20 kHz to remove the liquid that entered the elongated pore. As a result, it was found that removal of the liquid entered into the very small pore having a square section with a side length of 0.6 mm. It was also observed that the time required to remove the liquid was shorter than 200 ms, and the liquid removal rate was over 95 %.

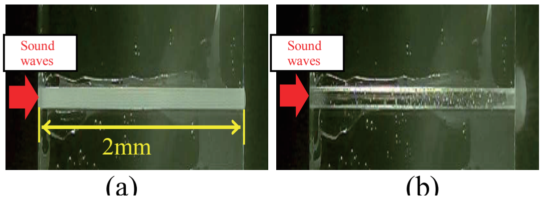

Fig.3 Behavior of liquid irradiated ultrasonic waves

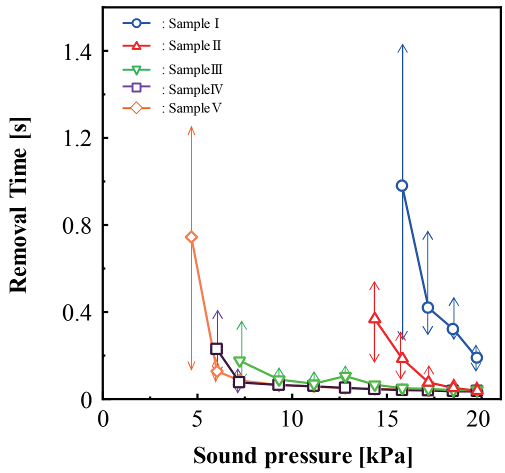

Fig.4 Relationship between time required to remove liquid and sound pressure

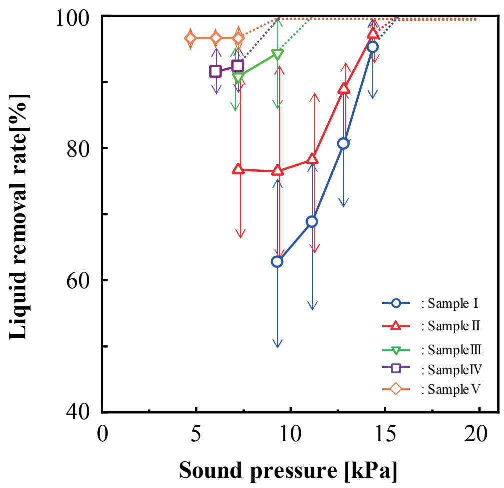

Fig.5 Relationship between liquid removal rate and sound pressure

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