K3-26

# Measurement of Acoustic Pressure Distribution in Ultrasonic Vibration Pipe

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In this study, the measurement of acoustic pressure distribution was conducted with LDV instead of a microphone as a non-destructive measurement method. To confirm the validity of measurement of acoustic pressure with LDV, laser was traversed on antinode and compared with microphone. Then the measurement of acoustic pressure distribution in 50mm diameter vibration pipe was carried out with LDV. As the result of this, the acoustic pressure distribution similar to the vibration mode was measured in 50mm diameter pipe.

## 1. Introduction

Experiment in which ultrasonic are applied to a horizontal pipe of a plug conveying was conducted and the effect of friction reduction by ultrasonic on all conveying conditions using 4 kinds of particles was shown by Dr. Kofu[1]. As a factor of this reduction effect, Hirai[2] has indicated the acoustic pressure. Friction between particles and the pipe wall decreases because particles are moved upward by the acoustic pressure difference when acoustic pressure distribution appears. Then, the research results by Hirai can be closely connected with a prediction of acoustic pressure effect on plug conveying. To realize this, acoustic pressure distribution in a vibration pipe needs to be predicted although it has not been clarified. In the past research, acoustic pressure in pipes was measured by Suzuki[3], but expected results could not be obtained. Then, the purpose of this research is to measure the acoustic pressure distribution in pipe with LDV that is a non-destructive measuring instrument.

## 2. Experimental Apparatus

An oscillator, amplifier and bolt-clamped langevine type transducer are connected as shown in Fig.1. A voltage of frequency *f*=20.5 kHz is generated by an oscillator because the resonance frequency of the piezoelectric device in a bolt-clamped langevine type transducer is 20.5 kHz. This voltage is amplified to 55 dB by the amplifier, and then input into the piezoelectric device, and ultrasonic vibration is generated. This vibration is amplified by the exponential horn. To connect the horn and vibration plate, and to transmit maximum vibration to the plate, a resonance rod is used. The resonance rod length is 124mm.

## 3. Experimental Methods

### 3.1 Measurement of the Vibration Mode

The voltage is generated by the oscillator and ultrasonic vibration is generated on each vibration pipe (then $A_m$=0.1μm). As shown in Fig.1, LDV are traversed every 10mm in axial direction and every 5degree in circumferential direction, and amplitude is measured to confirm that the vibration mode.

### 3.2 Validity of Measuring Acoustic Pressure with LDV

Acoustic pressure between the vibrating and the reflective plates is measured with the microphone as a preliminary experiment. Then the suitability is investigated by comparing the measured value of the microphone with LDV as shown in Fig.2.

### 3.3 Measurement of Acoustic Pressure with LDV

$A_m$=0.1μm was set at 50mm diameter pipes and acoustic pressure distribution appears. When laser was traversed in the pipe, laser is refracted by the acoustic pressure and this is measured as voltage. Then the acoustic pressure distribution is obtained by converting the measured value into SPL with Eqs. (1)-(2).

$$p[\mathrm{Pa}] = 8.19 \times 10^4 \times \frac{50[\frac{\mathrm{mm}/s}{\mathrm{V}}] \times V_{LDV}[\mathrm{mV}]}{f[\mathrm{kHz}] \times l[\mathrm{mm}]} \qquad (1)$$

$$P_{SPL}[\mathrm{dB}] = 20 \times \log \frac{P[\mathrm{Pa}]}{20\times10^{-6}[\mathrm{Pa}]} \qquad (2)$$

LDV is set to the *x*-*y*-*z* table and acoustic pressure is measured. The measurement is conducted every 2mm in *x* and *y* direction from the center of each pipe.

## 4. Result and Discussion

Figs.4 and 5 shows the results of measuring the flexural vibration on each pipe. They show the vibration mode was obtained as designed. So measurement of acoustic pressure distribution was

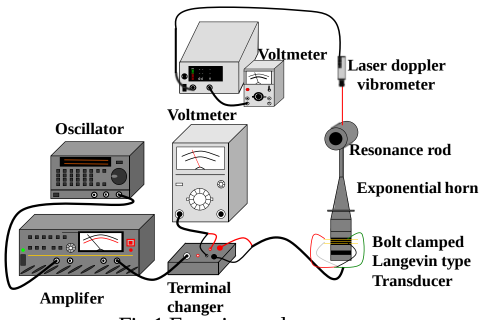


Fig.1 Experimental apparatus

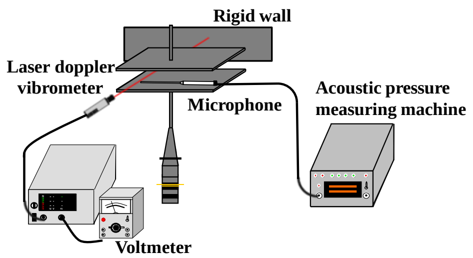
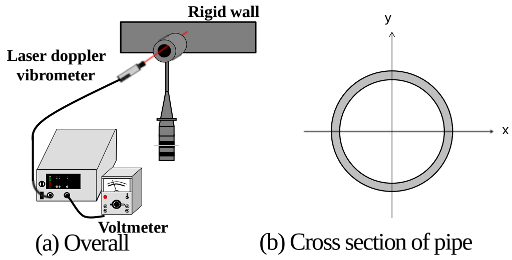


Fig.2 Experimental apparatus



(a) Overall (b) Cross section of pipe

Fig.3 Experimental apparatus

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conducted with these vibration pipes. Fig.6 shows the results of measuring acoustic pressure with microphone between 2 plates. It can be seen that acoustic pressure value did not change in laser direction at each amplitude even though amplitude changed. Fig. 7 shows measured value of acoustic pressure with LDV is almost equivalent to the value with the microphone. Therefore, it was validated that acoustic pressure can be measured with LDV. Fig.8 shows the result of the measuring acoustic pressure in 50mm pipe diameter with LDV. It can be seen that the measurement value is large between center and pipe wall similarly to vibration mode. From this figure, the mode of acoustic pressure distribution was obtained. Moreover, the measured value at the center of the acoustic pressure distribution is small. It can be considered that sound waves generated from each antinode are canceled each other at the center of the pipe.

## 5. Conclusion

1) The vibration mode was obtained as designed because the acoustic pressure is constant in axial direction and 8 antinodes appear at each pipe.
2) The measured value with LDV was equivalent to the value with the microphone. Therefore, the measurement of acoustic pressure can be conducted with LDV.
3) In 50mm pipe, 8 antinodes of acoustic pressure appears equivalently to the vibration mode.

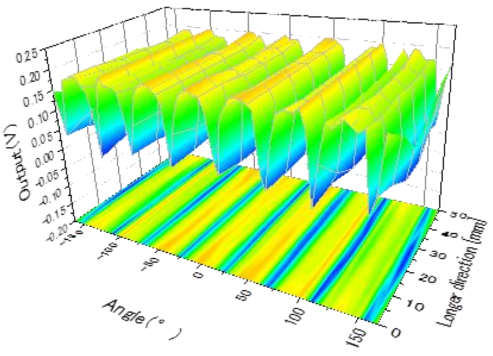


Fig.4 Measurement of amplitude ($\varphi$=50mm, $A_m$=0.1μm)

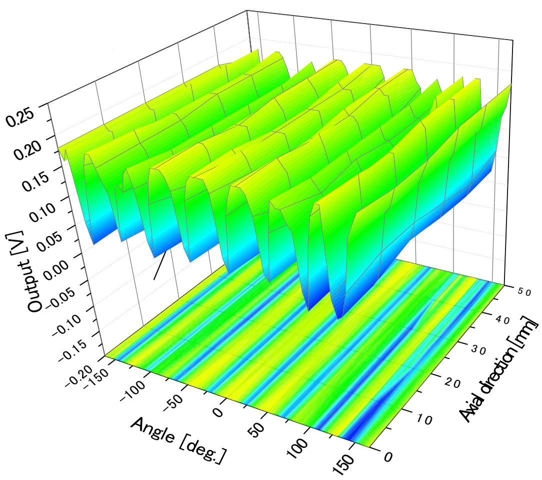


Fig.5 Measurement of amplitude ($\varphi$=60mm, $A_m$=0.1μm)

## 6. References

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[2] K. Kofu, M. Ochi, H. Miura, Y. Hirai : Influence of Acoustic Pressure on Wall Friction Reduction Effect by Ultrasonic, *J. Soc. Powder Technol. , Japan*, 47, 4, 222-229, 2010

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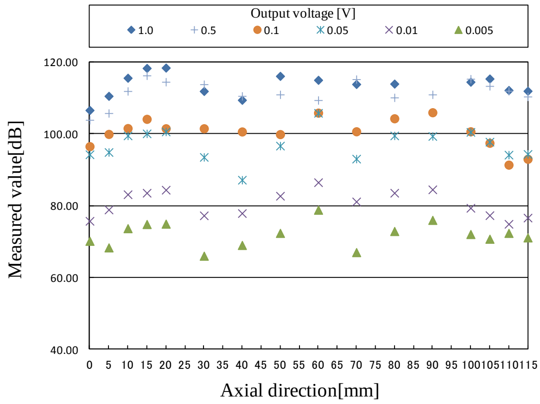


Fig.6 Measurement of acoustic pressure

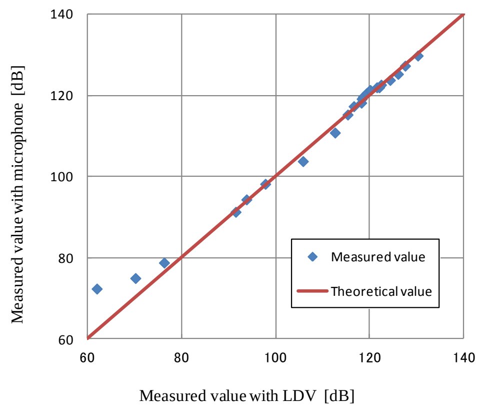


Fig.7 Comparison between value of acoustic pressure measured with microphone and LDV

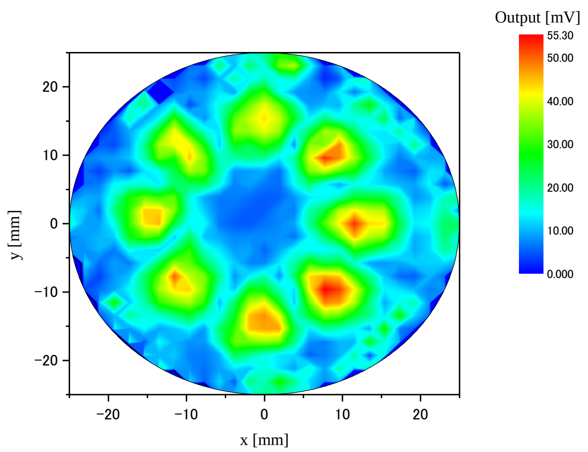


Fig.8 Acoustic pressure distribution measured with LDV ($\varphi$=50mm, $A_m$=0.1μm)