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Continuous measurement of particle size using a combination of resonance flexural vibration modes of a circular disc.

円盤のたわみ共振モードの組み合わせを用いた粒径連続測定

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1. Introduction

Sand and small stones moving on a riverbed (bed load) cause the topographical changes such as local lowing and scouring[1]. The measurement of the size distributions of the bed load is important to prevent river disasters, and robust and simple particle sizer without electric power supply is required[2]. In this report, continuous measurement of particle size by a passive piezoelectric sensor was investigated.

2. Methods

Fig. 1 shows the structure of the piezoelectric sensor used for the experiment which consists of an aluminum disc (diameter: 100 mm; thickness: 2 mm) and a PZT annular ultrasound transducer (inner diameter: 20 mm; outer diameter: 30 mm; thickness: 2 mm). When particles hit the sensor surface, the flexural vibration is excited and the electric signal is generated through the piezoelectric effect. The fundamental, second, and third resonance frequencies of the flexural vibration on the sensor surface were 4.5, 17.4, and 36.3 kHz. The vibration distribution at the sensor surface at each resonance frequency were measured using a laser Doppler vibrometer (LDV, NLV-2500, Polytec) by applying an input voltage of the continuous sinusoidal wave at each resonance frequency. The measurement experiments of the particle size were conducted using crushed stones. The particle size distribution of the crushed stone was classified into three gravel groups (ϕ < 3 mm, 3 mm < ϕ < 7 mm, and 7 mm < ϕ) by sieves. The particles were allowed to fall freely and continuously from the height of 150 mm to the sensor surface in air, and the waveform of the electric signal generated by the collisions was observed with a digital oscilloscope (RIGOL, DS 1054Z) and the frequency analysis was performed for each collision. The measurement time was 2.1 s and the sampling frequency was 500 kHz.

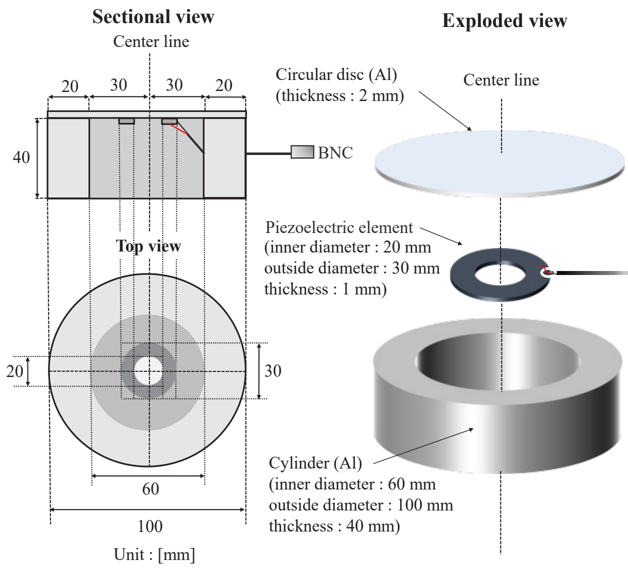

Fig. 1 Configuration of the piezoelectric particle sizer.

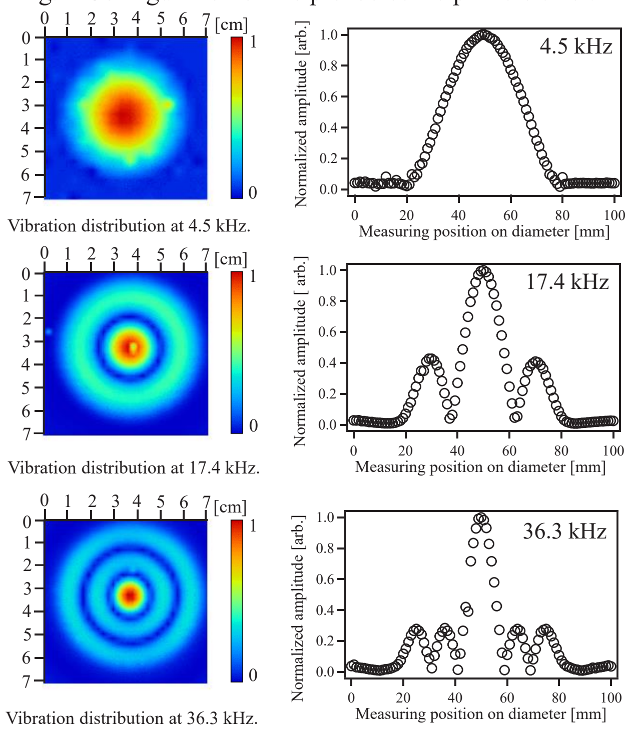

Fig. 2 Vibration distributions of the disc at the resonance frequencies of 4.5, 17.4, and 36.3 kHz.

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3. Results and discussions

Fig. 2 shows the vibrational displacement amplitude distributions at the sensor surface at the resonance frequencies. The flexural vibration was generated at each frequency and larger number of the concentric nodal circle of the flexural vibration appeared at higher resonance mode. **Figs. 3(a) and (b)** show the one representative example of experimentally observed output waveform and its frequency spectrum, respectively. In Fig. 3(b), three peaks corresponded to the resonance frequencies of 4.5, 17.4 and 36.3 kHz, and the amplitude of the frequency peaks depended on the particle size. Here, we defined the spectrum amplitudes at 4.5, 17.4, and 36.3 kHz as A, B, and C, respectively, so that a spectral parameter R to discriminate the particle size can be defined as $R = A / (B + C)$.

Fig. 4 shows the representative output signal obtained by the sequential collisions of the particles on the sensor for 2 s. Multiple impulsive waveforms were generated and overlapped by the collisions, and the particle size distribution can be estimated by the parameter R through the frequency analysis of the whole signal. **Fig. 5** shows the histograms of R for three particle size groups (ϕ < 3 mm, 3 mm < ϕ < 7 mm, and 7 mm < ϕ). Here, the average values of R were 1.58, 4.93, and 9.02, respectively; larger particle resulted in larger value of R. The relative variation of R, which was a ratio of the standard deviation to the average value were 0.74, 0.67, and 0.74, respectively, indicating the relative variations were almost constant.

Fig. 6 shows the particle size distribution for the group of 3 mm < ϕ < 7 mm predicted from the experimental result of R shown in Fig. 5. For comparison, the particle size distribution for 500 samples measured by a micrometer was also shown. The two average values showed a good agreement and the particle size distribution could be estimated by the spectral parameter R.

4. Conclusion

A method to measure the particle size distribution using the piezoelectric sensor was investigated. The correlation between the spectral ratio of flexural resonance modes and the particle size was confirmed, indicating the effectiveness of particle size distribution measurement. We intend to develop the theoretical model for measurement in future research.

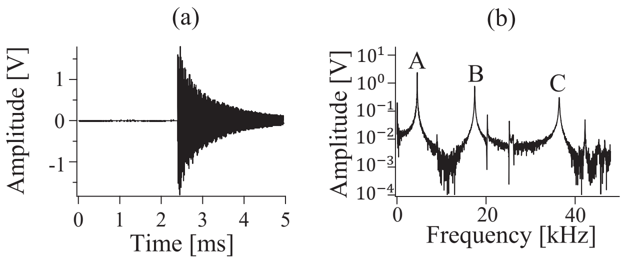

Fig. 3(a) Output waveform and (b) the frequency spectrum generated by a single impact of the center part of the sensor by a particle with 3 mm < ϕ < 7 mm.

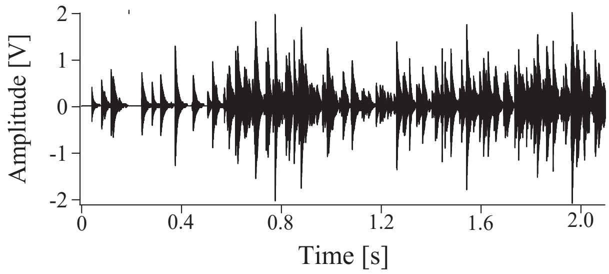

Fig. 4 Output signal by the sequential impacts of the particle with 3 mm < ϕ < 7 mm.

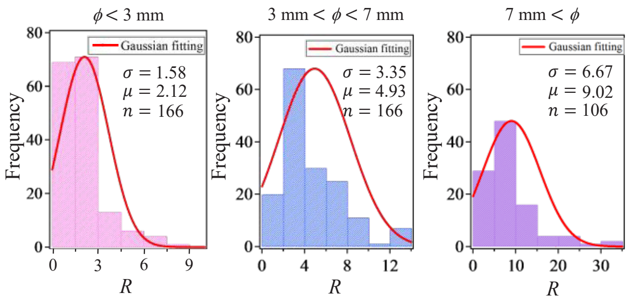

Fig. 5 Histograms of R for three particle size groups (σ: standard deviation; μ: average value; n: number of collisions).

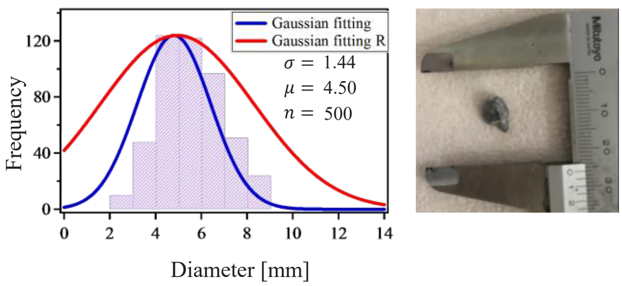

Fig. 6 Comparison of the particle size distributions (3 mm < ϕ < 7 mm).

References

1. T. G. Drake, R. L. Shreve, W. E. Dietrich, P. J. Whiting, and L. B. Leopold, J. Fluid Mech., vol. 192, pp. 193-217, 1988
2. H. Takebayashi, J. Fluid Mech., vol. 24, no. 1, pp. 27-36, 2005