K3-24

Influence of Acoustic Pressure and Flexural Vibration on Friction Reduction Effect by Ultrasonic

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Abstract: The influence of acoustic pressure and flexural vibration on friction reduction effect by ultrasonic has been investigated in this study. The relationship between friction reduction of particles by each effect and the particle density has been shown by using of ultrasonic. Additionally, the maximum of particle density which could receive the friction reduction effect by the acoustic pressure has been expressed. In order to evaluate the reduction effect by acoustic pressure and flexural vibration, firstly, the distribution of acoustic pressure between reflection plate and the vibration plate have been measured. As a result, it was clarified that acoustic pressure distribution became the almost same whether ultrasonic was applied for the upper or lower plate, and the reflection plate vibrated little. Therefore it was possible to divide the influence of acoustic pressure and flexural vibration on the friction reduction.

1. Introduction

The authors have researched the handling of particles in various industries by ultrasonic. One of them, ultrasonic was applied to plug transportation to reduce the transportation power and formulate a theoretical method that can predict this effect accurately. This also showed that ultrasonic can reduce the pressure drop regardless of the kind of particles and transportation condition. The purpose of this research is analyzing the influence of acoustic pressure and flexural vibration.

2. Experimental Apparatus and Method

An oscillator, amplifier and bolt-clamped langevine type transducer are connected as shown in figure 1. A voltage of frequency f=20.5 kHz is generated by an oscillator. This voltage is 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 vibration mode of the plate is shown in figure 2 when a 20.5 kHz frequency voltage was input.

2-1）Acoustic Pressure Distribution

Ultrasonic is applied to only one of plates. Then the acoustic pressure distribution is measured when each plate is vibrated. If the acoustic pressure distribution is the same between the vibrating plates, it can be said that the effect by acoustic pressure can be evaluated. The ultrasonic was given to upper and lower plate individually while l was set at 27 and 29 mm, and the acoustic pressure was measured. In this time, acoustic pressure loss in the probe tube occurred since this tube was so long. The equation (1) represents the relationship between the acoustic pressure with the probe tube and without the tube. P_m is the acoustic pressure measured by probe tube. Consider using this P.

$$P = 1.0974 P_m \qquad (1)$$

2-2）Plate Vibration Amplitude

Ultrasonic gives only the upper plate. Voltage V is measured by the laser Doppler meter at the origin, the amplitude was calculated from Eq. (2).

$$A_{m0} = 0.0017 V_l \qquad (2)$$

2-3）Effect of Acoustic Pressure and Flexural Vibration

While the following conditions from a) to c) were set, the entire equipment setup was slowly tilted in the y direction until scattered particles began to move. This direction means the parallel to the vibration mode, and then the angle the angle was measured 5 times and the average of each condition was defined as α. Tangent α is equal to the friction coefficient μ. The particle properties are shown in table 1.

$$\mu = \tan\alpha \qquad (3)$$

a) Without ultrasonic vibration

b) Both plates were vibrated. Friction is reduced by acoustic pressure and flexural vibration

c) Only upper plate was vibrated the acoustic pressure

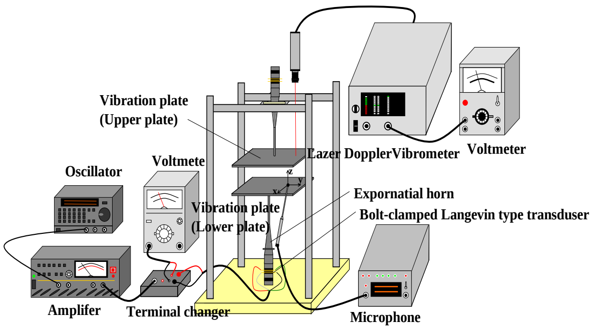

Fig.1 Experimental apparatus

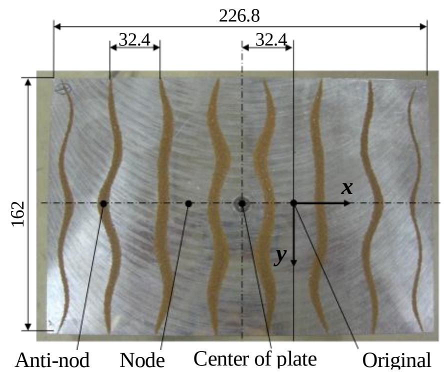

Fig. 2 Vibration plate

Table1 Particle properties

Particles	Mean particle diameter d_p [μm]	Particle density ρ [g/cm^3]
Polystyrene	80	1.11
Aluminum		2.76
Ceramic		3.85
Titanium		4.48
Stainless steel		7.65
Iron		7.83

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3. Experimental result

3-1) Acoustic Pressure Distribution

The result of the acoustic pressure distribution of l=27mm at the position of z=0mm is shown in Figure 3. The acoustic pressure distribution in the z direction at the origin is shown in figure 4. These figures shows that the difference of the acoustic pressure distribution is small, even though the ultrasonic is given to each plates.

3-2) Plate Vibration Amplitude

The amplitude of the upper plate and lower plate are shown in figure 5. The amplitude of the lower plate which has not given the ultrasonic is very small compared with the amplitude of upper plates. Therefore, acoustic pressure fluctuation generated little vibration for the plate which ultrasonic is not applied.

3-3) Effect of Acoustic Pressure and Flexural Vibration

The relationship of particle density and friction coefficient ratio is shown figure 6. This figure means the reduction effect by acoustic pressure and flexural vibration. Moreover, these figures show the friction coefficient ratio approaches gradually to 1.0 as ρ_s increases. In short, it can be said that the friction reduction effect by acoustic pressure is not available. Figure 7 clearly shows that ρ_{s0} increases with the increase of ΔP. Therefore, it can be said that the maximum particle density, which can realize the friction reduction effect by acoustic pressure, becomes larger.

4. Conclusion

(1) The friction reduction effect by acoustic pressure can be expressed quantitatively.

(2) The limitation for the particle density that obtains the friction reduction effect by the acoustic pressure is shown, and this maximum density becomes larger as the pressure difference near the wall becomes larger.

(3) The experimental method using two plates can be applied to investigate the influences of acoustic pressure and flexural vibration separately, because the acoustic pressure distribution is almost the same regardless of which plate receives the ultrasonic, and the plate is little vibrated.

5. References

[1] K.Kofu, M.Ochi, M.Takei and Y.Hirai Pressure Drop Reduction by Applying Ultrasonic for Plug Transportation of Granular Particles, *J.Soc.Powder Technol.,Japan*, 46, 12,858-864, 2009

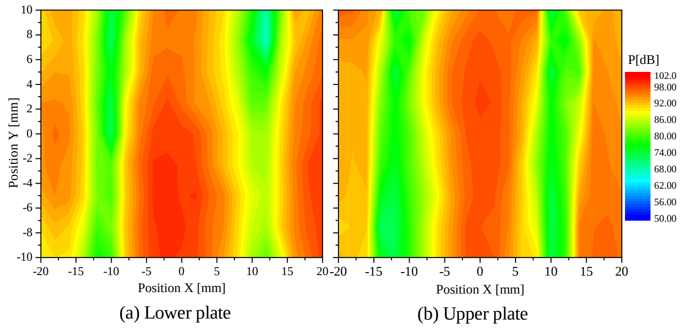

Fig.3 Acoustic pressure distribution in dimension of x-y

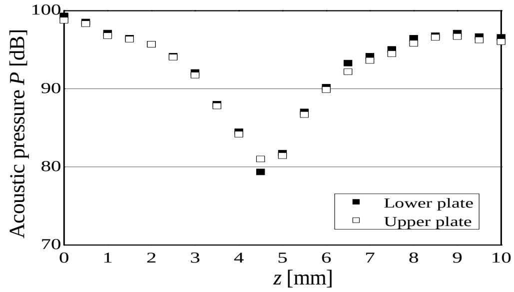

Fig.4 Acoustic pressure distribution (l=27mm)

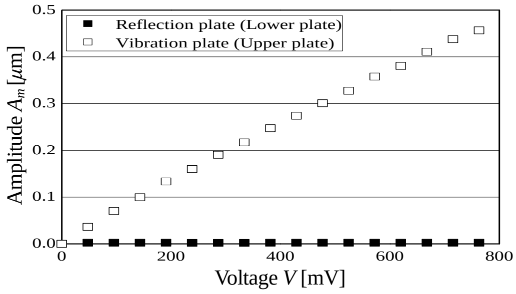

Fig.5 Relation of input and Amplitude (l=27mm)

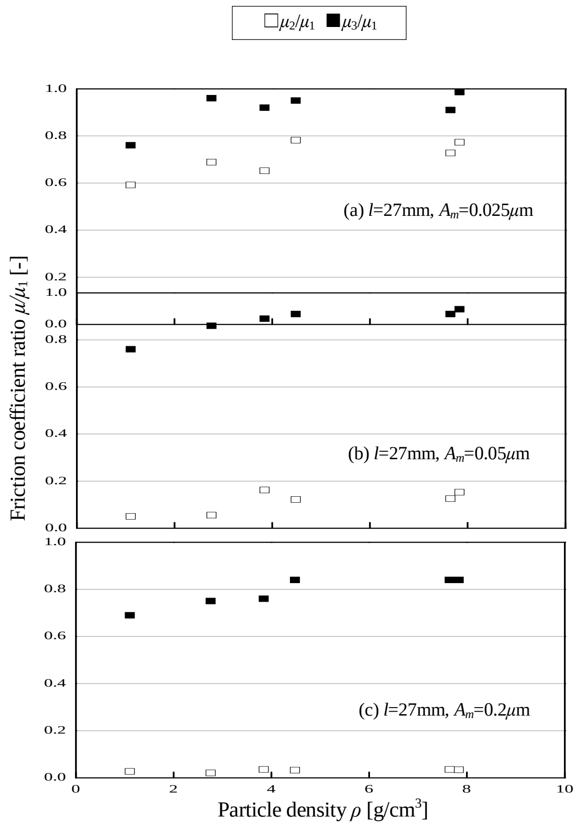

Fig.6 Relation of particle density and friction coefficient

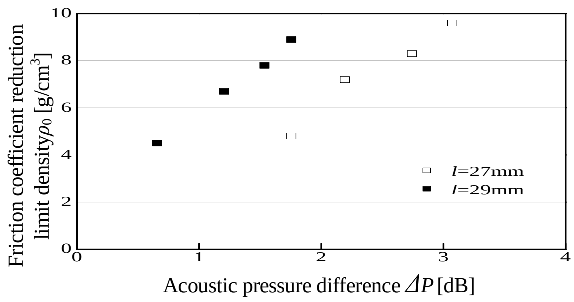

Fig.7 Relation of acoustic pressure difference and maximum particle density