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Agglomeration experiment using enlarged volume by two ultrasonic sound sources using cylinder type vibrating plate

容積を拡大した 2 台の円筒形振動板型空中超音波音源による凝集実験

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1. Introduction

Fine particles in exhaust gas, such as factory flue gas, have adverse health effects, and thus dust collectors that remove small, fine particles like PM2.5 are becoming more widely used. We have developed a dust collection method using ultrasonic waves [1], and we are investigating using a cylindrical vibrating plate to improve the fine particle agglomeration efficiency of powerful aerial ultrasonic sound sources [2].

In this paper, we used a cylinder to expand the sound field in conventional agglomeration equipment and examined the effect on fine particle agglomeration.

2. Configuration of the agglomeration chamber

Figure 1 shows a schematic of the agglomeration chamber, which consists of two aerial ultrasonic sources and cylinders for expanding the sound field. One ultrasonic source consists of a 27 kHz bolt-clamped Langevin ultrasonic transducer, an amplitude exponential horn, and a resonance rod for djusting the resonance frequency of the longitudinal vibration, which are connected with screws. A cylindrical flexural vibrator (material, A 2017; overall length, 100 mm; inner diameter, 80 mm; outer diameter of vibration section, 85.4 mm; outer diameter of rigid wall section, 148 mm) with a rigid wall integral structure is fixed to the tip of the sources by screws [3]. An acrylic sound field expansion cylinder is placed between two sound sources and both ends of the cylinder have an inner diameter of 80 mm, equal to that of the diaphragm, an outer diameter of 100 mm, and a length of 100 mm.

3. Sound field inside the cylinder

The sound pressure inside the agglomeration column was measured by a microphone with a probe. In the measurements, the sound source was driven at 27.51 kHz, which is the resonance frequency of the two vibrators, and two sound sources were simultaneously driven with 1 W/unit of input power. The results are shown in **Fig. 2**. The horizontal axis shows the position in the direction of the central axis of the cylinder, and the vertical axis shows the position in the direction of the cylinder cross section. The origin of the vertical and horizontal axes is 170 mm from the right end on the central axis of the agglomeration chamber. Sound pressure is normalized by the maximum value, which is shown in red. High sound pressure was achieved on the central axis.

4. Configuration of agglomeration chamber

Figure 3 shows a schematic of the

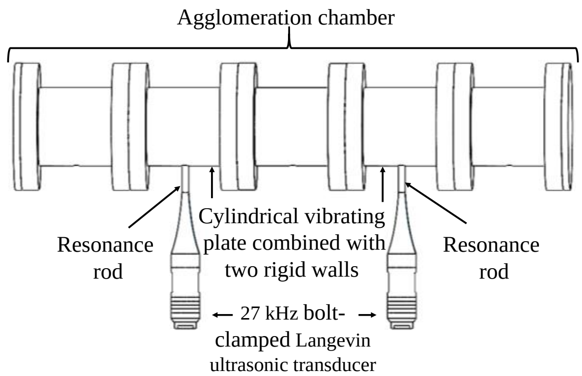

Fig. 1. Schematic of the acoustic agglomeration device.

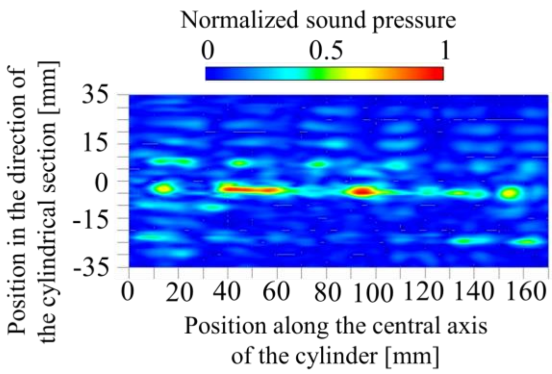

Fig. 2. Sound pressure distribution in the cylinder.

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measurement system used in this study. The aerosol concentration was measured by a densitometer (Model 8530, Tokyo Direct). Incense (light blue cloud violet, part number 24911, NipponKodo) was used to generate smoke. The main particle size of the incense smoke was 1.0 µm or less.

5. Aerosol agglomeration experiment

To examine aerosol agglomeration by aerial ultrasonic waves, the concentration of the aerosol discharged from the agglomeration chamber was measured keeping the initial concentration constant and varying the input power of the ultrasonic source. The air flow rate to the agglomeration chamber was kept constant at 1.0 L/min, the temperature was 27–28 °C, and the humidity was 50–73%.

The measurement was started at 0 s when 3 burning incense sticks were put into the aerosol generating chamber, and continued for 1200 s. Ultrasonic waves were applied for 300 s from 600 s to 900 s. Measurements were performed three times for each of the two sound sources at various input powers, and the average concentrations were calculated.

Figure 4 shows experimental results. The horizontal axis shows the elapsed time and the vertical axis shows the aerosol mass concentration. ON and OFF in the figure indicate the presence or absence of ultrasonic irradiation. Before the ultrasonic wave irradiation, the concentration became saturated and constant. The concentration decreased rapidly when the ultrasonic wave irradiation was applied, and the larger the input power, the larger the decrease was. This is because the vibration amplitude of the particles increased with the ultrasonic wave irradiation and made them easier to aggregate.

Next, the agglomeration efficiency was examined. Using the average value of the concentration over 5 s (595–600 s) immediately before the ultrasonic wave irradiation was turned from OFF to ON (C_1) and the average value of the concentration for 5 s (895–900 s) immediately before the ultrasonic wave was turned from ON to OFF (C_2), the agglomeration efficiency (E) was calculated as

$$E = \left(1 - \frac{C_2}{C_1}\right) \times 100 \qquad (1)$$

The calculated agglomeration efficiency is shown in **Table 1**. The agglomeration efficiency was similar for the total input powers of 20–30 W, and reached a maximum at 40 W.

6. Conclusions

The agglomeration of an aerosol using two aerial ultrasonic sources was examined. The agglomeration efficiency reached 87% at a total input power of 40 W.

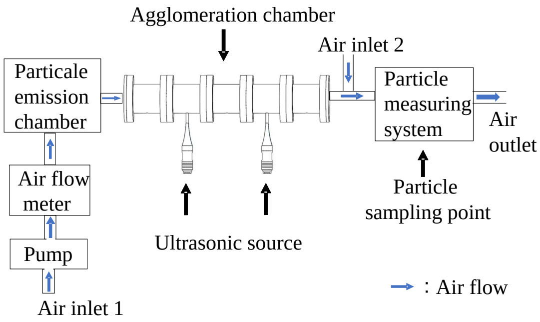

Fig. 3. Block diagram of measurement system.

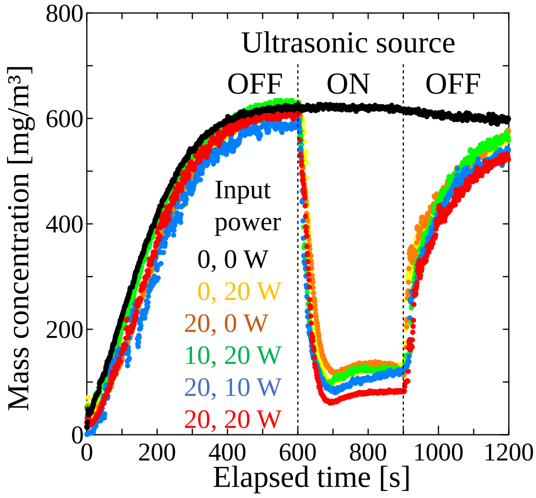

Fig. 4. Relationship between mass concentration and elapsed time.

Table 1. Relationship between input power and aggregation efficiency.

Input power [W/unit]	0 - 20	20 - 0	10 - 20	20 - 10	20 - 20
aggregation efficiency [%]	80	81	81	79	87

Acknowledgment

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