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Characteristics of particle size distribution of agglomerates in an ultrasonic source with a cylindrical rigid wall
円筒剛壁一体型音源による煙霧質凝集の粒径分布の特性

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1. Introduction

Fine particles in exhaust gases such as factory flue gas have an adverse effect on health; thus, dust collectors for removing fine particles, such as PM2.5, are required. Ultrasonic dust collectors improve the dust collection efficiency of fine particles by agglommerating the particles with ultrasonic waves as a pretreatment [1].

We have been studying the agglomeration of fine particles using ultrasonic waves to improve the agglomeration efficiency. The agglomeration rate for ultrasonic agglomeration is higher (agglomeration rate of 74%) when the air flow rate to the agglomeration chamber is 0.5 L/min. In this paper, the particle size distribution under the conditions that give the highest dust collection efficiency was measured for fine particles in ultrasonic wave agglomeration.

2. Agglomeration device

The agglomerator consists of an ultrasonic source and an agglomeration chamber (**Fig. 1**). The ultrasonic sound source is composed of a 28-kHz bolt-clamped Langevin ultrasonic transducer and a vibrating plate combined with the rigid wall of a cylindrical rigid wall integral structure. The agglomeration chamber consists of an acrylic cylinder connected to an ac vibrating plate combined with the rigid wall. A standing wave sound field is formed inside the cylinder and a strong sound field is obtained near the central axis. When the driving power is 20 W, the sound pressure was 169 dB at the antinode of the standing wave sound field at the central axis of the cylinder.

3. Configuration of the agglomeration device

Figure 2 is a block diagram of the agglomeration device for aerosol collection. The device consists of an air pump, a flow meter, an aerosol generating chamber, and an agglomeration chamber, and each part is connected with a transparent tube (inner diameter: 8 mm). The air flows in order through the air pump, the aerosol generating chamber, and the agglomeration chamber, as indicated by the blue arrows in the figure, and is released from the air outlet. A burning incense stick was used to generate fine particles[2] with a main particle size of 1.0 μm[2], which was suitable for this study.

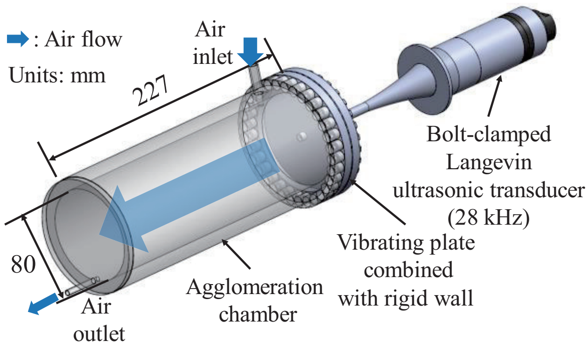

Fig. 1. Schematic of the device for acoustic agglomeration.

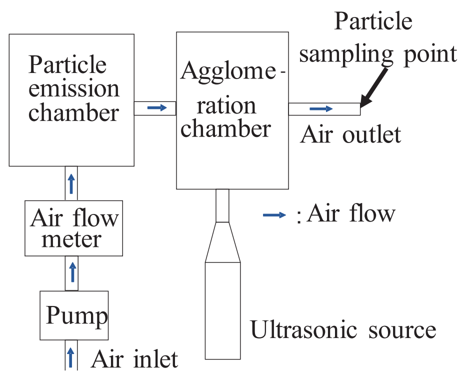

Fig. 2. Block diagram of the measuring device.

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4. Measurement of particle size distribution of agglomerated fine particles

To investigate the agglomeration effect of fine particles by ultrasonic irradiation, the particle size distribution was measured under the conditions where the agglomeration rate was the highest. The measurement conditions were an input power to the sound source of 10 or 0 W, and an air pump air flow rate of 0.5 L/min. Four incense sticks were used. The total experimental time per session was 1200 s after the incense stick was placed in the aerosol chamber. Ultrasonic irradiation was performed for 150 s from 1050 s to 1200 s, when the smoke concentration was nearly stable. The pump was stopped after the experiment, and 200 mL of air inside the agglomeration chamber was collected by suction using a syringe at the air outflow port of the agglomeration chamber. The fine particles were allowed to adhere to a glass dish for 1 h, and were photographed (20 sheets, total area of 0.23 μm^2) using a microscope (magnification factor of 2500). The particle size was determined using image processing software (ImageJ).

The center diameter (d_{50}) was used as an evaluation method. The center diameter is a particle diameter ratio of 5:5 of particles on the large and small sides when the measured particle diameters are divided into two, and similarly, d_{10} is a particle diameter ratio of 1:9, and d_{90} is a particle diameter ratio of 9:1.

Figure 3 shows the measurement results without ultrasonic irradiation. The horizontal axis represents the particle size, and the vertical axis represents the frequency distribution (left axis, black bars) and cumulative distribution (right axis, red line). The total number of particles was 1664, d_{10} was 0.85 μm, d_{50} was 1.25 μm, and d_{90} was 2.0 μm, and there were almost no particles with a particle size of 3.5 μm or more. **Figure 4** shows the distribution for an input power of 10 W, with the same the horizontal and vertical axes as in Fig. 3. The total number of particles was 823, d_{10} was 1.8 μm, d_{50} was 5.6 μm, and d_{90} was 13.2 μm, indicating that there was a wide range of particle sizes.

Ultrasonic irradiation reduced the total particle number by about 50%, and increased the particle size of the fine particles by 2.1 times for d_{10}, 4.5 times for d_{50}, and 6.6 times for d_{90}. In a previous study[2] using an air flow rate of 1.0 L/min, the particles obtained at each representative diameter were smaller than those in the present study, indicating that an increased agglomeration effect.

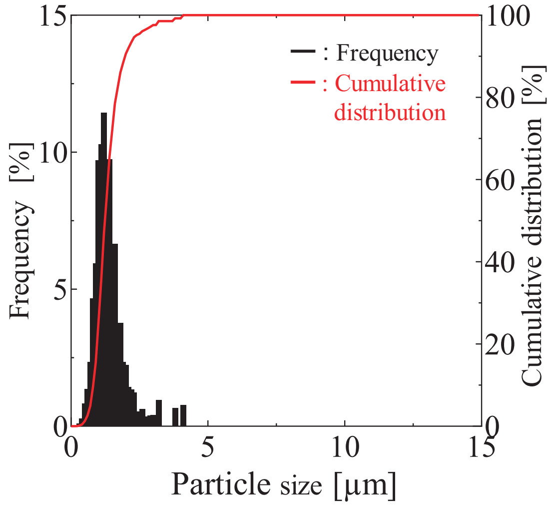

Fig. 3 Particle size distribution without ultrasonic irradiation.

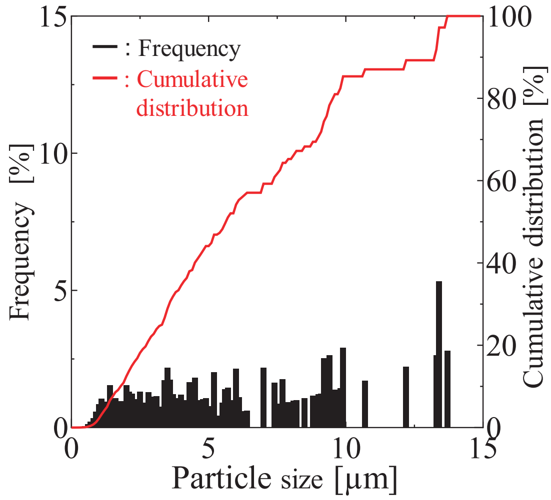

Fig. 4. Particle size distribution with ultrasonic irradiation of 10 W.

5. Conclusions

We investigated the agglomeration of fine particles using aerial ultrasonic waves and measured the particle size distribution under the conditions that gave the highest agglomeration rate. At a flow rate of 0.5 L/min, particles larger than 10 μm were observed, and the increased particle size indicated an enhanced agglomeration effect.

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Reference

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2. R. Motoi, T. Asami, H. Miura, Proc. Na-tional Spring Meet Acoust. Soc.Jpn.(2019).3pp.111-112.(in Japan)