1Pa4-2

Examination of aerosol agglomeration using two small aerial ultrasonic sources

Yuki Ono[1‡], Takuya Asami[1], and Hikaru Miura[1] ([1]Nihon University)

1. Introduction

The agglomeration of fine particles is an example of the use of aerial ultrasonic waves. In ultrasonic agglomeration, particles suspended in air are irradiated with ultrasonic waves, which induce collisions between particles and increase the particle size[1]. We examined the aerosol agglomeration in devices with different volumes using one ultrasonic source to allow device miniaturization and we showed that the size of the volume affects the agglomeration rate. In this study, we fabricated agglomeration devices with different volumes using two ultrasonic sources and examined the effects of input power and volume on the agglomeration effect.

2. Configuration of agglomeration device

Figure 1 shows the three agglomeration devices with different volumes. The blue line in the figure shows the cohesive section. The apparatus consisted of a rectangular cohesive section made of an acrylic plate with an ultrasonic source. The ultrasonic source was inserted into the acrylic plate, and flange of the source was fixed to the plate with the vibrating surface of the sound source facing the opposite side of the cohesive section. The ultrasonic sources comprised a 60 kHz bolt-clamped Langevin transducer, a flanged uniform rod, and a transmission rod for adjusting the longitudinal vibration resonance frequency, all of which were mounted with screws, and a circular vibrating plate with a round groove at its tip. The drive frequency was 59.0 kHz. The dimensions of each device were determined by analysis in the y-axis direction so that the volume ratio of the cohesive section was 1:2:3. The internal lengths of the three devices were 17 mm for both the x- and z-axis directions, and the y-axis direction for devices 1, 2, and 3 was 87.2, 174.8, and 261.9 mm, respectively. In each agglomeration device, there was a hole through which the air flow tube passed that was 4.4 mm away from the vibrating plate and the reflection wall.

3. Sound field inside the agglomeration devices

The sound field was measured by frequency response analysis with COMSOL Multiphysics to confirm the sound field in the dimensions of the cohesive section of the agglomeration devices. **Figure 2** shows an example of the results for device 1. The analysis conditions were a frequency of 59.0 kHz, a length of 17.0 mm in the x-axis direction, and a length of 87.2 mm in the y-axis direction. The color bar in the figure shows the sound pressure normalized by the maximum sound pressure. Cold colors indicate low sound pressure and warm colors indicate high sound pressure. The origin of the coordinates is the position of the center of the ultrasonic source on the left side of the agglomeration device. The sound field in the figure is in the x-y plane at z = 0 mm. The antinodes and nodes of the sound pressure occurred alternately in the y-axis direction, forming a standing wave sound field. The distance between the antinodes of the sound pressure in the y-axis direction was 3 mm, which corresponded to half a wavelength of a sound wave with a frequency of 59.0 kHz. The y-z plane at x = 0 mm had a similar sound field.

4. Outline of experimental equipment

Figure 3 shows a schematic of the experimental

E-mail: csyk21009@g.nihon-u.ac.jp, asami.takuya@nihon-u.ac.jp, miura.hikaru@nihon-u.ac.jp

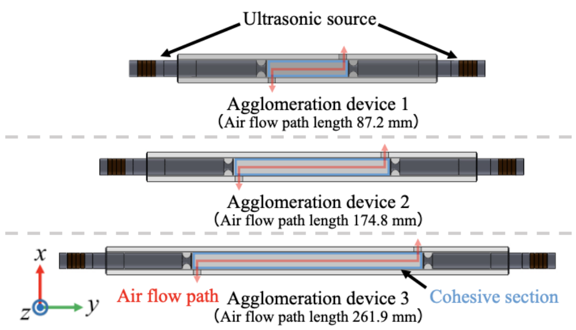

Fig. 1. Schematic of agglomeration devices.

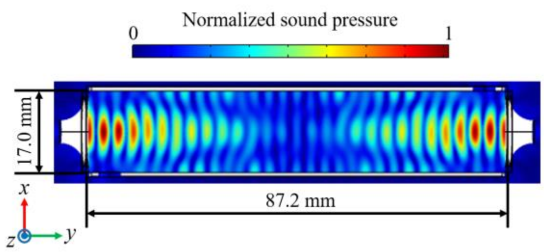

Fig. 2. Sound field of agglomeration device 1.

equipment. The experiment was carried out at a constant air flow rate of 0.4 L/min. An incense stick was placed in the particle emission chamber, the air was taken in from the air suction port, and the aerosol was introduced into the cohesive section. The concentration was measured with a densitometer after ultrasonic agglomeration. The measurement was started at 0 s when the burning incense stick was put into the particle emission chamber, and it continued for 1200 s. Ultrasound was emitted from 600 s when the concentration was relatively stable and was applied for 5 min until 900 s. The input power was constant at 6 W for all the agglomeration devices, and the measurements were performed three times each and the average was taken.

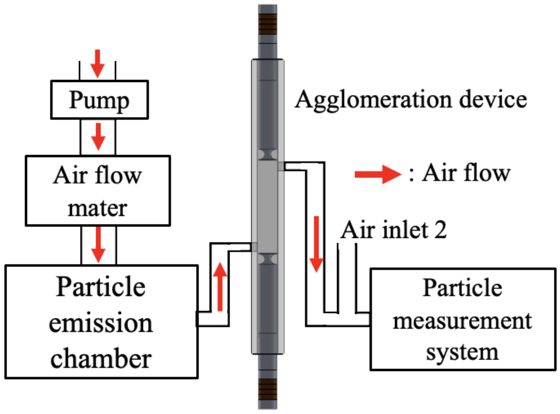

Fig. 3. Agglomeration experimental equipment.

5. Agglomeration experiment

Figure 4 shows the results of the aggregation experiment using devices 1, 2, and 3. The vertical axis of the figure is the mass concentration normalized to the mass concentration before ultrasonic irradiation (580–590 s), and the horizontal axis is the elapsed time. The black line shows the results without ultrasonic irradiation, the red, blue, and green lines show the results for devices 1, 2, and 3, respectively, with 6 W input power. With no ultrasound irradiation, the concentration increased up to 600 s, and then increased slowly from 600 to 1200 s. With ultrasound irradiation, the increase in concentration was the same as that with no irradiation up to 600 s, and then the concentration decreased sharply during ultrasound irradiation, from 600 to 900 s. From 900 s onward, after the ultrasound was stopped, the increase in concentration was the same as that with no irradiation and the concentration approached that with no ultrasound irradiation. The decrease in concentration was in the order device 3 < device 2 < device 1, indicating that the aerosol concentration decreased as the flow path in the cohesive section become shorter. Next, to compare the agglomeration effect, agglomeration efficiency E was calculated from the following equation.

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

Here, C_1 is the mean concentration before (580–590 s) and after (910–920 s) ultrasound irradiation, and C_2 is the mean concentration during ultrasound irradiation (630–870 s). The calculated agglomeration efficiency is shown in **Table 1**. The agglomeration efficiency increased with decreasing volume at an input power of 6 W.

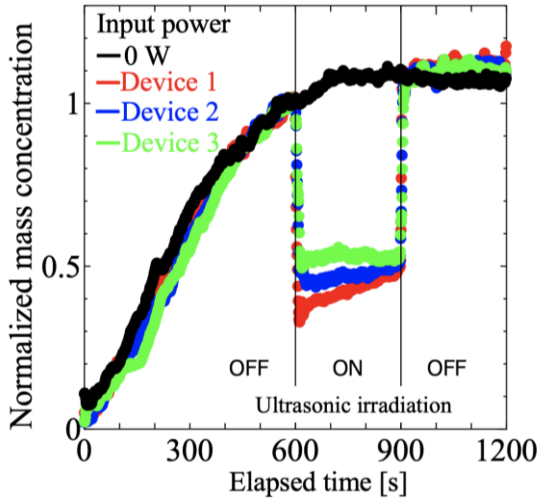

Fig. 4. Agglomeration experiment results.

Table 1. Agglomeration efficiency.

	Volume [cm^3]	Input power [W]	Agglomeration efficiency [%]
Agglomeration device 1	25.2	6	60
Agglomeration device 2	50.5	6	55
Agglomeration device 3	75.7	6	48

6. Conclusions

In this paper, we developed agglomeration devices with different volumes equipped with two small aerial ultrasonic sources, and we examined their aerosol agglomeration at a constant input power. The agglomeration efficiency increased with decreasing volume, and an agglomeration effect of 60% was obtained with agglomeration device 1.

Acknowledgment

This work was partially supported by JSPS KAKENHI Grant Number 18K11700.

References

1. Yusuke Hoda, Takuya Asami and Hikaru Miura, Jpn. J. Appl. Phys. 61, SG1073, 2022.