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Removal Promotion of Low Hydrophilic Gas by Aerial Ultrasonic Waves adding two different particles of spraying water.

空中超音波による粒径の異なる大小の水霧を付加した場合の親水性の低いガスの除去促進

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1. Introduction

Pollutant gases in the air can have adverse effects on human health and the environment depending on the gases' constituents; the presence of these potentially harmful air pollutants is now becoming a social problem. Hence, collection and removal of such gases by using aerial ultrasonic waves and water mist is proposed.

Recently, gas removal effects have been studied experimentally by using lemon oil vapor (hereafter called ‘‘lemon gas’’), gas which is a hydrophobic gas. Lemon gas is beneficial for use in gas removal experiments because it has the following characteristics: (1) nontoxicity to humans, (2) usability under typical temperatures and pressures, (3) hydrophobicity, and (4) ease in determining its concentration.

The results of experiments using lemon gas show that a gas removal rate of up to 40% is achieved in an intense standing wave at 20 kHz, when the amount of water mist is 1.39 cm^3/s and the electrical input power is 50 W. Increasing the surface area of the water mist is leads to greater removal of hydrophobic gas.

In this study, experiments are run to study the effects on gas removal of using intense aerial ultrasonic waves to disperse water mist with different particle sizes: small particles (diameter: ≈3 μm) and conventional large particles (diameter: ≈60 μm).

2. Gas Removal Apparatus and Experimental Methods

Figure 1 shows a schematic of the gas removal apparatus. The ultrasonic vibration source consists of a 20 kHz bolt-clamped Langevin-type transducer, an exponential horn (large end diameter: 70 mm; small end diameter: 10 mm; amplification factor: ≈7.0; length: 150 mm; material: duralumin); and a longitudinal vibration half-wavelength resonance rod (diameter: 10 mm; length: 112 mm; material: duralumin), and a square plate vibrating in a transverse lattice mode (length: 217 mm; thickness: 3 mm; resonance frequency: 19.84 kHz; material: duralumin).

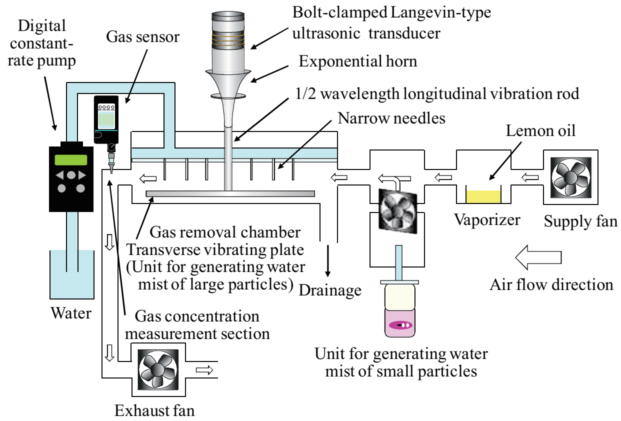

Fig.1 Schematic of gas removal apparatus.

In this experiment, lemon gas is brought into contract with the water mist of small particles after the vaporizer.

Lemon oil is poured into a container in the vaporizer. The lemon gas to be removed from the air transferred continuously into the gas removal apparatus by fan continuously (flow rate: 1.6×10^{-3} m^3/s). The fan is operated for 180 s before measurements are taken, such that the lemon oil is vaporized at a constant rate.

After the 180 s delay, water mist of small particles is sprayed, and simultaneously electrical power is supplied to the ultrasonic source to produce aerial ultrasonic waves. Additionally, water mist of large particles is sprayed by supplying water through narrow needles above the vibrating plate.

A heated-wire semiconductor gas sensor is used to measure the concentration of lemon gas.

3. Experimental Results

3.1 Confirmation of Gas Removal Process

To examine the lemon gas removal process, the lemon gas concentration with respect to the

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elapsed time was measured when the electrical input power was constant at 50 W, both with and without the water mist of large particles (amount of water mist: 0 or 2.78 cm^3/s), and with and without the water mist of small particles (amount of water mist: 0, 0.08, or 0.32 cm^3/s).

Figure 2 shows the results, where the vertical and horizontal axes represent the gas concentration and the elapsed time, respectively. According to Fig. 2, the gas concentration without any water mist (solid line) stays almost constant between 0～600 s when ultrasonic waves are applied. In contrast, the gas concentration with the water mist of large particles initially decreases rapidly for all amount of water mist of small particles (dot line: 0 cm^3/s, dash line: 0.08 cm^3/s, dot-dash line: 0.32 cm^3/s) when ultrasonic waves are applied, and the concentration then levels off, declining negligibly. The gas concentration decreases as the amount of water mist of small particles increases. After stopping application of ultrasonic waves (at 600 s), the gas concentration increases to near the initial gas concentration.

It is clear that both the water mist and ultrasonic waves are needed to promote the removal of lemon gas.

3.2 Removal Effect for Various Initial Gas Concentrations

To observe the effect on lemon gas removal of the initial lemon gas concentration, the lemon gas concentration was measured with respect to the elapsed time, and the removal efficiency for the initial gas concentration was computed, when the electrical input power, and the amount of water mist of large and small particles were kept constant at 50 W, 2.78 cm^3/s, and 0.32 cm^3/s, respectively. The removal rate, *Rr*, is defined as

$$Rr = \frac{G_a - G_b}{G_a} \times 100\,[\%] \qquad (1)$$

Here, G_a [g/m^3] is the average gas concentration from elapsed time: -180 s to 0 s (before applying the ultrasonic waves), and G_b [g/m^3] is average gas concentration from elapsed time 500 s to 600 s (when applying ultrasonic waves).

Figure 3 shows the removal efficiency results. The vertical and horizontal axes in Fig. 3 represent the removal rate, *Rr*, and the initial gas concentration, respectively. According to Fig. 3, the removal rate tends to increased with the gas concentration when the electrical input power, and the amount of water mist of large and small particles, are kept constant. This trend is attributed to the water mist having a greater opportunity to collect gas at a high gas concentration.

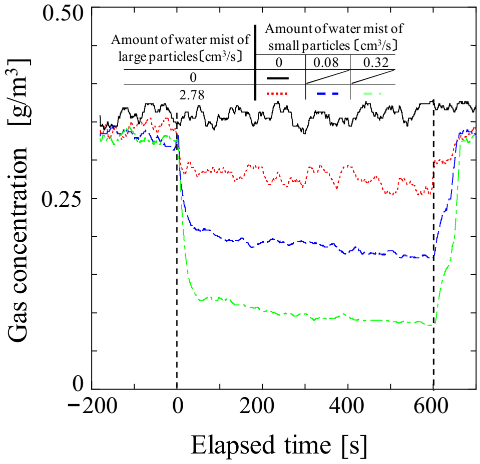

Fig.2 Gas removal process. Electrical input power is 50 W.

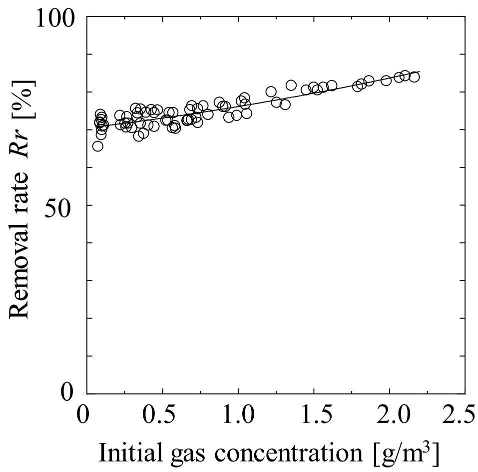

Fig.3 Relationship between initial gas concentration and removal rate. Electrical input power is 50 W, amount of water mist of large particles is 2.78 cm^3/s, and amount of water mist of small particles is 0.32 cm^3/s.

4. Conclusions

In this study, lemon gas removal was investigated through experiments using intense aerial ultrasonic waves with two different particle sizes of water mist: small droplets and conventional large droplets. From the results, the following conclusions were reached.

(1) Both spraying water and ultrasonic waves are needed to promote the removal of lemon gas.

(2) The removal rate tends to increase with gas concentration.

References

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