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Effect of flow rate on washing rate for ultrasonic washing with running water

流水式超音波洗浄における流量の変化に対する洗浄効果

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1. Introduction

3D printers[1] use additive manufacturing methods, such as fused deposition modeling, in which products are fabrics through the lamination of a plastic such as ABS resin or PLA resin. Depending on the shape of the product, a support material[2] may be required to serve as a base to prevent the unhardened resin from bending, with the support material removed after the fabrication is complete.

There are various methods for removing the support material, including the use of tools, water-soluble support material, washing liquid and an ultrasonic cleaner, and high-pressure water. However, there are problems with each of these removal methods. For example, removing the support material using tools may be labor-intensive, small parts may be impossible to remove completely, and the object may be damaged. In contrast, ultrasonic washing in running water can shorten the removal time of the support material and can be used for objects of any shapes.

In this study, the relationship between washing rate and flow rate in ultrasonic washing with running water is examined.

2. Device for ultrasonic washing in running water

The ultrasonic vibration source is composed of a bolt-clamped Langevin vibration transducer (D4427PC, Honda Electronics; 27 kHz, 40 mm in diameter, and 90 mm in length) and an exponential horn (diameter of thick end face: 40 mm; diameter of thin end face: 8 mm; material: duralumin) with an overall length of 111 mm.

Figure 1 is a schematic diagram of the experimental device. The exponential horn was covered with an acrylic pipe from the flange to the thin end. An outlet (acrylic pipe) was attached to the tip. Tap water was used for washing. The water flowed from the inflow port (blue arrow) and ultrasonic waves were applied through the ultrasonic vibration plane, water flows to the outlet and hits the washed item. The water was supplied by a pump (NP-50, Nakasa) and the flow rate was adjusted with a valve.

An impedance analyzer (ZGA 5920, NF) was used to investigate the vibration characteristics of the ultrasonic vibration source. The impedance was measured with a fixed driving voltage of 1 V_{rms}, and with no load (in air) or with a load (in water flowing through the pipe at a flow rate of 1 L/min).

Figure 2 shows the conductance as a function

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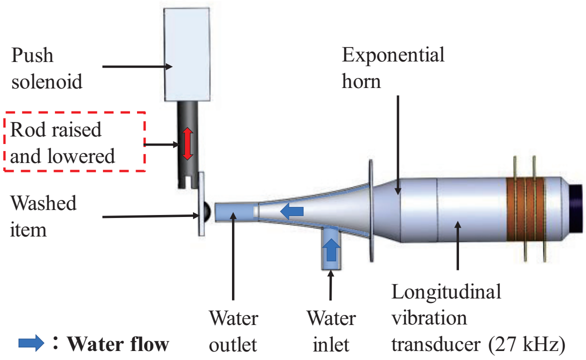

Fig. 1 Schematic of ultrasonic vibration source.

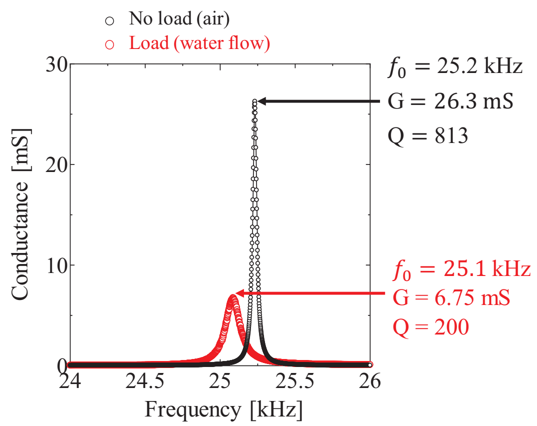

Fig. 2 Frequency characteristics of the vibration source.

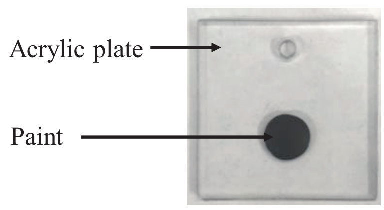

Fig. 3 Washed item.

of frequency. The conductance is shown along the vertical axis and the frequency is shown along the horizontal axis. The results for no load are shown in black and the results for water flowing through the pipe are shown in red. With no load, the resonance frequency was 25.2 kHz, the conductance was 26.3 mS, and the Q factor was 813. With the load of the water flow, the resonance frequency was 25.1 kHz, the conductance was 6.75 mS, and the Q factor was 200.

3. Experimental method

The sample for washing was attached to the tip of the bar of a rod-shaped push solenoid (CH 12840250, Takaha Kiko) to control the position of the sample in the water and the washing time. Before and after washing, the water did not come into contact with the sample because the solenoid rod was raised. During washing, the rod was lowered and the sample was placed in front of the water outlet.

Figure 3 shows a photograph of a paint sample, which consisted of an acrylic plate (40 × 40 mm) with an area covered with black water-based paint (0.25 g) to model dirt. The distance between the horn and the acrylic pipe was 1 mm.

4. Washing experiment

The washing time was 30 s, the input power was 0, 2, and 10 W, and 10 samples were cleaned for each input power. The washing rate was measured to determine the effect of changing the input power on the washing and was calculated by the gravimetric method using equation (1).

$$\text{Washing rate} = \frac{(W_S - W_W)}{W_S} \times 100\ [\%] \qquad (1)$$

Here, W_s is the amount of dirt before washing and W_w is the amount of dirt after washing. Before washing, the samples were dried in an oven (DRE 320 DA, Advantec), and then weighed. After the experiment, the samples were allowed to air dry for 24 h and were weighed using a universal electronic balance (MC 1000, Kensei Kogyo Co., Ltd.).

Figure 4 shows the washing rate as a function of flow rate for input powers of 0 and 2 W, and **Fig. 5** shows that for input powers of 0 and 10 W. The washing rate is shown on the vertical axis and the flow rate on the horizontal axis. The blue plot in Fig. 4 shows the cleaning rate at the input power of 2 W, and the black plot in Fig. 5 shows that at the input power of 10 W. The red plots in Figs. 4 and 5 show the cleaning rate for an input power of 0 W. The cleaning rate increased with the flow rate regardless of the input power. However, at 0 W, the increase in cleaning rate was small, whereas for a large input power, the increase was large. When the input power is high, a large amount of cavitation is generated in the pipe, and the sound field in the pipe is disturbed. It is considered that increasing the flow rate cause

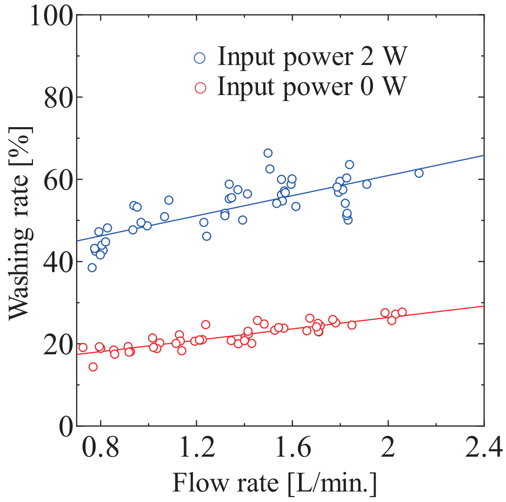

Fig. 4 Relationship between flow rate and washing rate for input powers of 0 and 2 W.

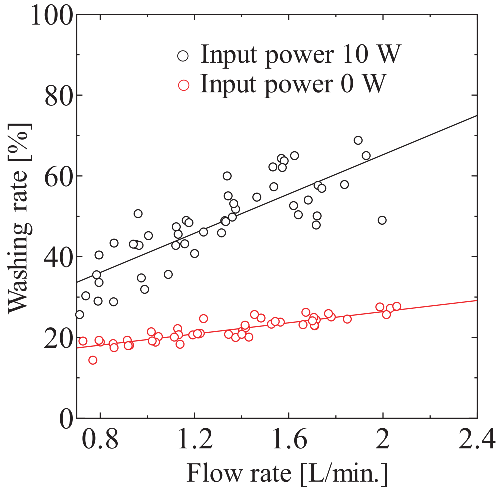

Fig. 5 Relationship between flow rate and washing rate for input powers of 0 and 10 W.

cavitation to flow[3], prevented cavitation from disturbed the sound field.

5. Conclusions

The relationship between the washing rate and change in flow rate in ultrasonic washing with running water was examined. Increasing the flow rate of running water irradiated with ultrasonic waves resulted in a larger cleaning effect.

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