A method of powder supply using an ultrasonic vibrating plate with multiholes

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A new equipment is developed to supply very fine powder using ultrasonic vibration. It has been well known that very fine powder inside a hopper forms easily powder-bridge. This behavior prevents the powder from continuously flowing. The author, however, utilizes the behavior in this study. Namely, the powder on a plate with multiholes of a suitable diameter can not flow out through the holes because of the powder-bridge, when the plate is not vibrating. On the other hand, the powder can flow out continuously, when the plate begins vibrating. The flow rate can be easily controlled by holding vibrational velocity of the plate at a fixed level. The paper deals with fundamental studies for this kind of powder supply.

Keywords: Powder supply, Ultrasonic vibration, Vibrational velocity, Vibrating plate, Hopper

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1. INTRODUCTION

Usually, flow rates of powders through a hopper have been controlled by a screw feeder or a vibrational feeder operated at a relatively low frequency (50 ~ 100 Hz) and a high amplitude level (0.1 ~ 0.5 mm). Contrarily, ultrasonic vibration is characterized by its high frequency and low amplitude, and it is supposed to be suitable to control powder flow at low level.

In the preliminary experiment, powders with relatively good fluidity were supplied from a pipe using a circular vibrating plate installed at the downstream end of the pipe. The powders were flowed out from an outer edge of the circular plate vibrating at a frequency of 20 kHz. It was found that the flow rates of powders were easily controlled by adjusting vibrational velocity of the plate.

However, it was found difficult to supply continuously the powders with poor fluidity by the method, since they formed easily powder-bridges inside a hopper. Contrarily, the author utilizes the behavior that powder forms bridges in this study. Namely, powder on a plate with multiholes of a suitable diameter can not flow out through the holes because of the powder-bridges, when the plate is at rest. On the other hand, it can flow out continuously, when the plate begins vibrating at an ultrasonic frequency of 20 kHz.

This phenomenon is caused by a vibrational sieve effect of the multihole plate. Therefore, it is considered to be possible to develop a new sieve system using the vibrating plate with multiholes of various sizes.

The diameter of the holes can be set in the range less than 4 mm for powder with poor fluidity. In this paper, vibrating plates with the holes of 2.0, 2.5, 3.0 and 3.5 mm in diameter were used and flow characteristics were investigated for carborundum powder of mesh 1,000 (18.0 ~ 14.5 μm in diameter).

2. POWDER SUPPLY SYSTEM

Figure 1 illustrates a sketch of the apparatus used for ultrasonic powder supply, composed of a hop-
per, a supplying pipe, a duralumin plate (1 mm in thickness, 80 mm in diameter) with multiholes and its driving system. It was used a Langevin type vibrator incorporated with a piezoelectric transducer operating at 20 kHz. Its maximum amplitude at the end of its horn was 20 μm (peak to peak).

If a rod to propagate vibration is straight, the vibrator must be set on the upper side of the hopper. But this makes it difficult to set some appliances inside the hopper, which prevents forming powder bridges inside the hopper. So a right-angled rod was attached to this apparatus, as shown in Fig. 1.

The plate was glued to the bottom of the supplying pipe with adhesive to prevent powder adhering to the inside surface of the pipe.

The flat surface of the vibrating plate is shown in Fig. 2. Multiholes of 3.5 mm in diameter were arranged radially and symmetrically into the plate. The number and diameter of holes in the plates are tabulated in Table 1.

The hopper and the supplying pipe were fulfilled with powder before supply experiment.

As mentioned already, powder could not flow out through the holes of the plate when the plate was at rest as illustrated in Fig. 3(a), while it began flowing out as the plate began vibrating as illustrated in Fig. 3(b). The plate was driven at a frequency of 19.48 kHz and its vibrational amplitude was calculated from the value of previously calibrated output voltage of a non-contact displacement meter ("Fotonic sensor") measured at the lower end of the rod.

The flow rate of powder was calculated from an average value of five times measurements of a lap time required for a certain amount of powder to flow out.

<table>
<thead>
<tr>
<th>Plate</th>
<th>Diameter of the hole (mm)</th>
<th>Number of the hole</th>
<th>Total area of the holes (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
<td>400</td>
<td>12.57</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>352</td>
<td>17.27</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
<td>258</td>
<td>18.23</td>
</tr>
<tr>
<td>4</td>
<td>3.5</td>
<td>192</td>
<td>18.47</td>
</tr>
</tbody>
</table>
3. RESULTS AND DISCUSSION

To determine difference in effects on vibration between a straight rod and a right-angled one, the vibrational amplitude of each case was measured as a function of the driving voltage of the vibrator.

Figure 4 shows relation between the driving voltage and the amplitude measured at the lower end of rods. Both experimental values increase almost linearly with the increasing in the driving voltage and the effect of bending the rod on vibrational amplitude is scarcely observed. The results assures that no substantial inexpedience would occur in using the curved rod to vibrate the plate.

Figure 5 shows changes in vibrational modes of the plates with multiholes of various diameters when employing the supplying pipe having 75 mm in inner diameter. The vibrational amplitudes (R.M.S.) were measured at several points of the plate as a function of distance x starting from its center by keeping the driving voltage at a constant level (110 V). Since the Fotonic sensor required good reflectibility of light at each point, a piece of aluminum sheet was adhered on it.

The amplitudes decrease with increasing distance from its center on the whole, corresponding to the decrease in the flow rates of powder. Also, displacement of nodes is scarcely observed with increasing diameter of holes, however, the amplitude at the fixed driving voltage decreases.

Figure 6 shows relation between vibrational velocity $V$ and a flow rate per unit area of holes $Q/A$, where $Q$ and $A$ denote flow rate and the total area of holes, respectively. The vibrational velocity is described by $V = a\omega$, where $a$ is the amplitude at the lowest end of the rod and $\omega$ is angular velocity.

The flow rate per unit area is determined by vibrational velocity, for $V < 40$ cm/s, independent of the...
diameter of holes. On the other hand, it decreases somewhat with increasing diameter of holes for \( V > 40 \text{ cm/s} \). Hence, it is ineffective to increase the hole diameter in order to increase the flow rate per unit area. In Fig. 7, the relationship between the flow rate per hole and area of the hole at various vibrational velocity is shown. The flow rate tends to saturate with increasing amplitude level. When the plate diameter is fixed, increase in hole diameter results in decrease in number of the holes, since the available area for holes in the plate is limited.

Consequently, it suggests that it is more effective to change the diameter of the vibrating plate for adjusting the flow rate. Figure 8 shows an appearance of powder flowing out through multiholes of a vibrating plate. It reveals that the flow rate decreases from the center to the circumference of the plate corresponding to decrease in the amplitude as shown in Fig. 5.

4. CONCLUSION

Even very fine powders which are likely to form powder-bridge inside a hopper can be continuously supplied by flowing them through multiholes of a vibrating plate. The experimental results are summarized as follows;

1) The right-angled rod propagates vibration from the vibrator to the vibrating plate in the same way as the straight rod.
2) The flow rate of powder is determined by vibrational velocity of the plate.
3) The flow rate through the hole increases with increasing hole diameter. However, the effect of hole diameter on the flow rate is scarcely detected.

It is more effective to change the diameter of the vibrating plate for adjusting the flow rate.

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REFERENCES


Makoto Saito was born in Gunma, Japan in 1949. He received the B.E. degree in mechanical engineering from Ashikaga Institute of Technology in 1974. He has been engaged in researches on powder supply method using an ultrasonic vibrating plate and a vibrating coil spring and now he is a research lecturer in Department of Mechanical Engineering at Ashikaga Institute of Technology. He is a member of the Acoustical Society of Japan, the Japan Society of Mechanical Engineers and the Society of Powder Technology, Japan.