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Alignment of micro particles on a flat plate in liquid using MHz-standing wave field
メガヘルツ定在波音場を用いた液中平面上への微粒子整列

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1. Introduction

The grinding wheels containing micro hard grains are very attractive tools for finishing the surface of hard-brittle materials. There have been various investigations of alignment of grains in the wheels for improving grinding performance[1]. However, there is no effective method for alignment of the micro particles on a flat plate in liquid.

In this paper, a method to align micro particles along nodal lines on a flat plate by the MHz-standing wave field is investigated. A standing wave field is generated on the plate using a transducer and a reflector inclined symmetrically. The sound pressure distribution and interval of particle line are experimentally and numerically evaluated.

2. Experimental Procedure

Figure 1 shows the configuration of the experiments. A disk with transducer and a reflector plate were inclined symmetrically that the waves from the reflector may return to the transducer via the angled reflection at the surface of the substrate. Plane waves are assumed to propagate between the transducer and the reflector. The angle between the axis of the transducer/reflector and the substrate surface is defined as, θ in Fig.1. The standing wave field is generated as a result of interference of the emitted waves and reflected waves. The standing wave field makes the nodal lines which are perpendicular to the traveling direction of the plane wave on the substrate surface. The particles were periodically aligned at the nodal lines on the substrate surface. The transducer(HM-1630, Honda Electronics) is 18mm in diameter and 1.6 MHz in resonance frequency. The materials of the substrate and the reflector are stainless steel (SUS304). Aluminum Oxide (Al_2O_3) particles used for the experiments are 16μm in mean diameter. Table 1 summarizes the experimental conditions. The distances *Lt* and *Lr*, shown in Fig. 1, are fixed at 60 mm, 40 mm, respectively. The reflection angle θ is varied from 20 to 65 degrees.

First, the reflection angle was fixed at 45 degrees. The sound pressure distribution was estimated from the change in the optical path length which was measured using laser Doppler vibrometer[2]. Second, the effect of the reflection angle on the interval of particle lines was investigated. The interval was measured using an optical microscope and compared with the value calculated by Eq. (1) with the wavelength in water, λ.

$$l = \lambda/2\cos\theta. \qquad (1)$$

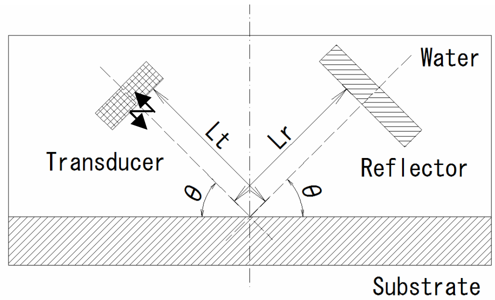


Fig.1 Configuration of Experiments

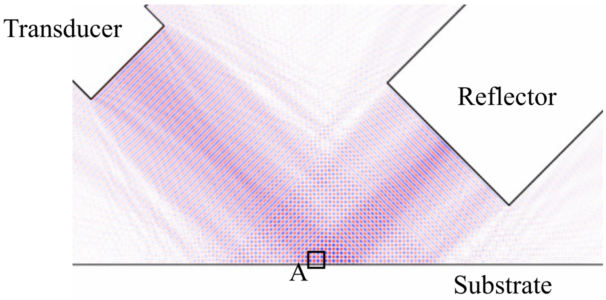
Table.1 Experimental Conditions

Resonance Frequency	1.6 MHz
Distance, Lt	60 mm
Distance, Lr	40 mm
Materials of Plate and Reflector	SUS304
Medium	Water
Particles	Al_2O_3, 16 μm in mean diameter
Reflection angle, θ	20～65 deg.

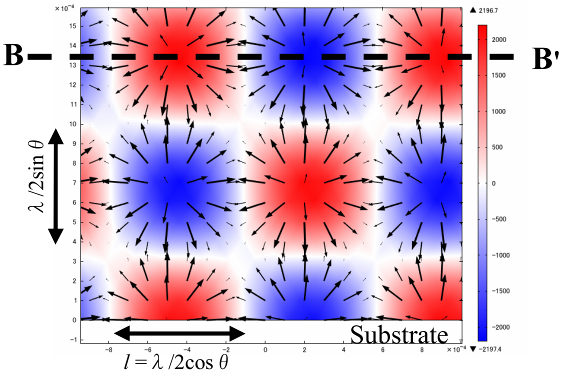
FEM analysis was also performed with the condition shown in Table 1 by using a commercial FEM tools (COMSOL Multiphysics). It is assumed that the transducer produces a perfect plane wave and that the reflections at the substrate and the reflector are total reflection.

3. Result and Discussions

Figures 3(a), (b) show the sound pressure distribution calculated by FEM at θ=45deg. Figure 3(b) shows enlarged view of area A in Fig. 3(a). The length and direction of arrows, in Fig. 3(b), shows strength and direction of acoustic radiation force, respectively. The light and shade



(a) Sound pressure distribution



(b) Enlarged area A

Fig.3 Sound pressure distribution by FEM analysis at θ=45deg.

indicate the degree of the sound pressure and light area is the node that is the low pressure area. The nodal lines are periodically existed. The interval of the nodal lines, which are perpendicular to the substrate surface, is $\lambda/2\cos\theta$. Acoustic radiation force is concentrated on the nodes. It is surmised that particles gather for the node line.

Figure 4 shows the measured and calculated sound pressure distribution on the line B-B' in Fig.3. Distance between the line B-B' and the substrate is twice of the interval between the nodes. The measured results were in good agreement with the calculated one in both amplitude and phase.

Figure 5 shows the optical microscope image of the particles aligned on the substrate by the standing wave field caused at θ=45deg. The particles were periodically aligned and the line of particles were perpendicular to the propagation direction of the ultrasonic waves. The area size of alignment is about 30 mm in X direction and is about 18 mm in Y direction. Intervals of particle lines are 0.5 ~ 1.0 mm wide in the reflection angle range 20 to 65 degrees.

Figure 6 shows the interval of particle lines as a function of the reflection angle θ. The measured intervals increased with increasing the angle θ and were in good agreement with ones calculated by Eq. (1). These results indicated that the intervals can be controlled by the reflection angle θ and wavelength of ultrasonic waves λ.

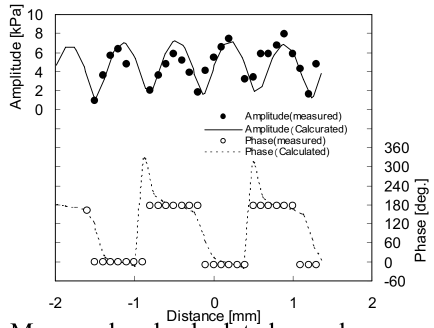


Fig.4 Measured and calculated sound pressure amplitude and phase on the line B-B' in Fig.3(b)

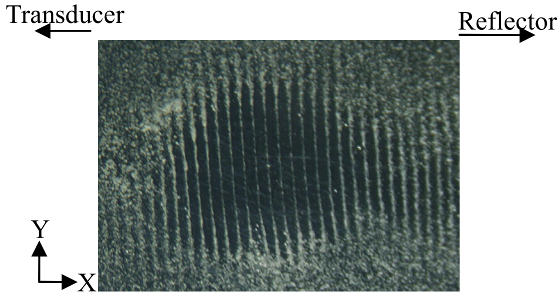


Fig.5 Microscope image of Experiment at θ=45deg.

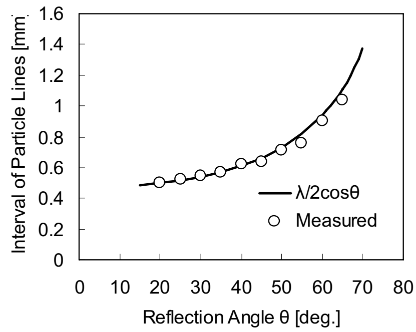


Fig.6 The variation of intervals of particle lines with the reflection Angle θ

4. Conclusions

The following conclusions were derived from the investigation about the alignment method for the micro particles by the MHz-standing wave field.

1. The particles were periodically aligned at the nodal lines caused by MHz-standing wave field on the substrate surface. The area size of alignment is 30 × 18mm. Intervals of particle lines are 0.5 ~1.0mm wide in the reflection angle range 20 to 65 degrees.
2. Intervals of particle lines can be controlled by reflection angle θ and wavelength λ

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References

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