Observation of jet emitted from through-hole in cylinder placed near vibrating surface

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1. Introduction

The planar object is levitated by the near-field acoustic levitation (NFAL) phenomenon over a vibrating surface[1-2]. The acoustic streaming generates an air gap between the vibrating surface and the levitated object. When the object has a small diameter through-hole at the center, acoustic streaming was ejected from the hole[3]. The jet from the hole was considered as shown in **Fig. 1**[3]. The velocity of the jet was increased with increasing vibration amplitude, decreasing air gap, and decreasing small hole diameter[3]. However, the flow distribution around the structure shown in **Fig. 1** has never been observed before.

The purpose of this study is to observe the flow field using a high-speed camera and elucidate by recorded movies.

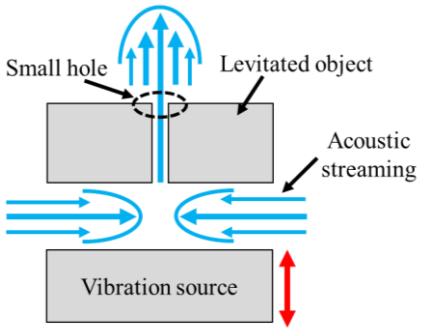

Fig. 1 NFAL and jet from a small hole[3].

2. Apparatus for Observation of Jet

Figure 2 shows the vibration source used in the experiment. The vibration source consists of a duralumin horn with a vibrating surface 10 mm in diameter and a bolt-clamped Langevin transducer and vibrates longitudinally at a resonance frequency of 28 kHz. **Figure 3** shows the cylinder part with a small hole in a plate for the jet. The material of the cylinder part is duralumin, and the thickness is 5 mm. The cylinder part is 10 mm in diameter and has a small hole of 1 mm in diameter. The sides of the vibrating surface and the plate were coated with a black spray to prevent the reflection of laser light from the sides.

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Fig. 2 Vibration source (resonance freq.: about 28kHz).

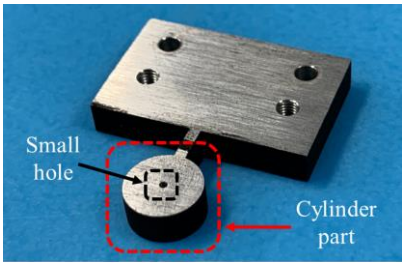

Fig. 3 The cylinder part with the small hole in the plate.

3. Observation method of Jet

Figure 4 shows the recording method for observation of the jet. The vibration source in **Fig. 2** was set inside the acrylic box with the vibrating surface down. The plate was fixed to overlap the vibrating surface and the cylinder part. The air gap between the vibrating surface and the cylinder was adjusted to 1 mm. The particle smoke was filled into the acrylic box to take the movie for the jet flow observation. The light sheet by the laser was irradiated from the left side in **Fig. 4**. The light sheet position was adjusted to pass at the center of the hole. Particle behavior in the acrylic box was recorded by the high-speed camera (Photron, FASTCAM Mini UX50) from the front of the box.

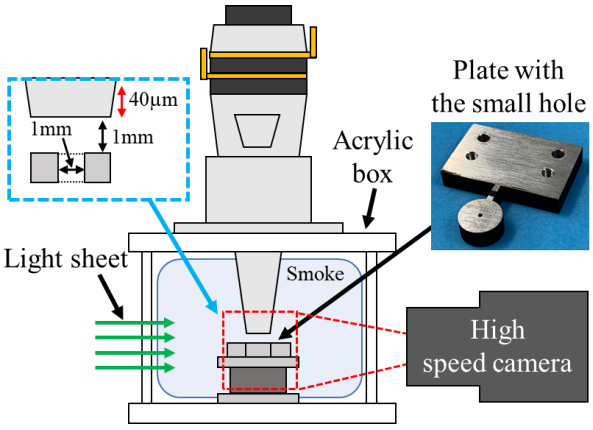

Fig. 4 Recording method for particles in the acrylic box, and setting values of vibration amplitude and air gap.

4. Observation Results

Figure 5 shows a photograph of illuminated particles around vibration source and the cylinder before driving. The areas surrounded by red and blue dotted lines are the vibration source shown in **Fig. 2** and the cylinder shown in **Fig. 3**, respectively. Particles illuminated by the sheet light were suspended around the cylinder, as shown in **Fig. 5**. **Figure 6** shows a photo of the particles during driving the vibration source. This photo is one frame of a movie recorded at 2000 fps. In this measurement, the vibration amplitude was controlled at 40 μm by an amplitude controller and a laser doppler vibrometer. The flow of particles in the area (A) in **Fig. 6** moved far away from the cylinder. The flow of the jet expanded farther away from the hole. The particles in the area (B) didn't appear to flow into the air gap. In addition, the flow in the area (C) was toward the small hole. Therefore, it was considered that the jet emitted from a small hole was generated by the absorption of air surrounding the hole, and not by flow through the air gap. This jet from the hole confirmed the presence of inflow and outflow areas close to the hole.

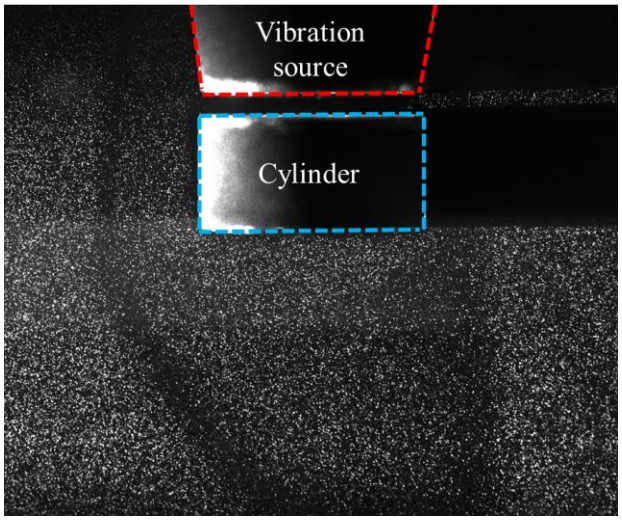

Fig. 5 Photo of illuminated particles around vibration source and the cylinder before driving.

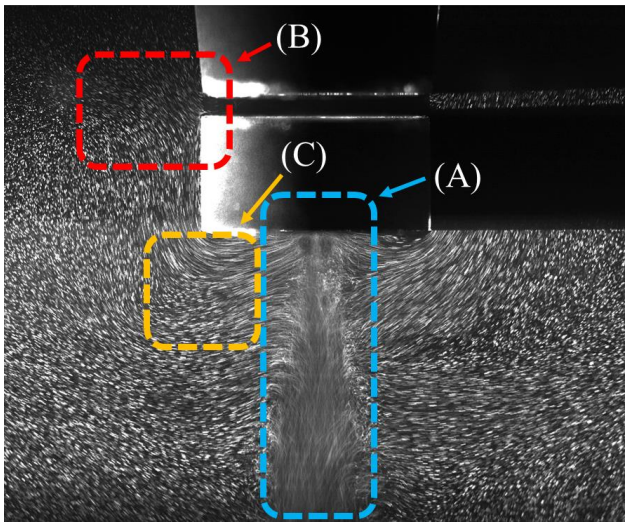

Fig. 6 Photo of flow around vibration source and the cylinder during driving.

5. Conclusion

The jet was observed using a vibration source, a cylinder with a through-hole and a high-speed camera. The flow distribution of the jet emitted from the hole was cleared by the observation of movies. During jet generation, the air didn't flow into an air gap between a vibrating surface and the cylinder. The air around the cylinder moved toward the hole, as shown **Fig. 7**. Therefore, the jet was considered to generate by the absorption of air surrounding the hole. In our future work, we intend to elucidate the mechanism of the jet from the hole and consider its application.

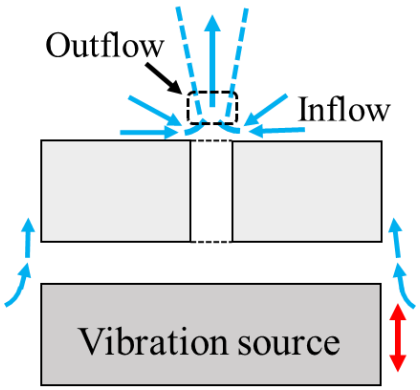

Fig. 7 Illustration of flow by the jet around the object with the through-hole.

Acknowledgment

This work was partially supported by JSPS KAKENHI Grant Number JP21H01268 and JST SPRING Grant Number JPMJSP2153.

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