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Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 431-432
20-22 November, 2013

Study on ultrasonic levitation using conventional sound systems – Application for industrial machines –

通常の音響系を利用した超音波浮揚の基礎研究 – 産業機器への応用の検討 –

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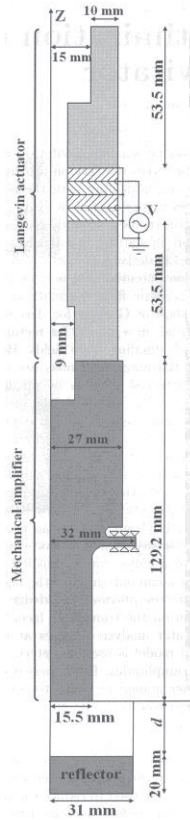
1. Introduction

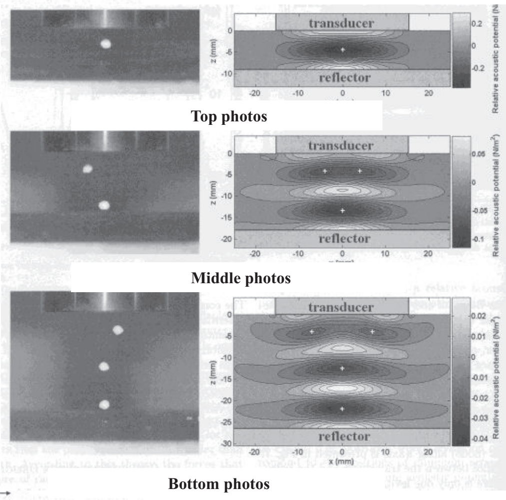
Levitations have been well-known phenomena in several media, such as magnetic, ultrasonic, electrostatic fields. Meissner effect is the most popular phenomenon to levitate supper conductive materials. However, its application is limited to specific area due to the requirement of extremely low temperature environment. As for ultrasonic levitation, theoretical calculation was conducted about 50 years ago. Its noticeable application was for Space Lab. In material experiments in Space Shuttle, the ultrasonic levitation was used to keep the materials in a chamber. There are a lot of demands to use such phenomena in industrial fields, especially in chemical, pharmaceutical areas, etc. However, today's levitation instruments limit their applications to very specialized requirements. Because Langevin-type transducers, whose sizes are a bit large, are used to excite high power ultrasonic waves of 130-150 dB. The peripheral devices to drive and control the transducers are also rather bulky.

In this paper, we investigate the possibility of employing conventional sound systems to levitation instruments. We propose a levitation machine with magnet-coil speaker drive mechanism to aim at wide industrial applications.

2. Present ultrasonic levitation instruments

There have been many papers about ultrasonic levitations. A typical Langevin transducer is shown in Fig. 1(a). Results at 19.9 kHz cited from the paper of M. A. B. Andrade, et al [1] are shown in Fig. 1(b). As simulation results illustrated in right figures, nodes (+ in the figures) of ultrasonic pressure sanding wave have ability of trapping particles. Styrofoam spheres are levitated in air at positions determined by the distances between the transducer and reflector as shown in left photos. But three points should be considered; (1) levitation area is small, (2) Langevin transducer is large, (3) external driver must provide very high voltages.





(b) Levitated results and simulation at 19.9 kHz (Top: d = 9mm, Middle: 18mm, Bottom: 26.5mm).

(a) Langevin-type transducer

Fig. 1 Today's levitation instruments and results (form M. A. B. Andrade, et al. [1]).

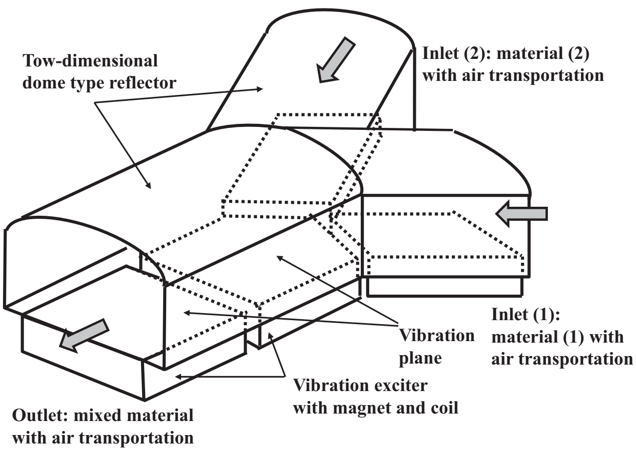


Fig. 2 Proposed structure to achieve ultrasonic levitation machine.

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3. Proposed levitation machine based on sound systems

In order to be adopted widely in industrial fields, the system should satisfy above three requirements. Several possibilities have been examined to replace Langevin transducers with other technologies. Frequencies from 20 to 40 kHz have been used in present systems, which may not be crucial especially in industrial applications. Conventional sound systems can warrant high sound power at frequency up to 10 kHz. So we propose a levitation machine based on magnet-coil vibration exciters. Two-dimensional dome type reflectors are introduced to transport input materials and output mixed materials by air as well as to reflect sounds as shown in Fig. 2.

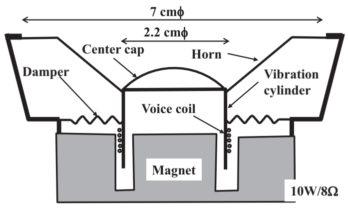
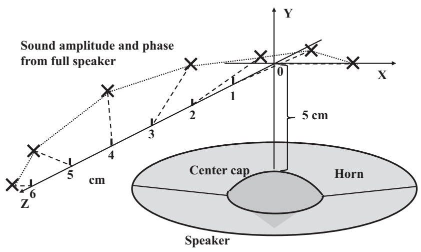
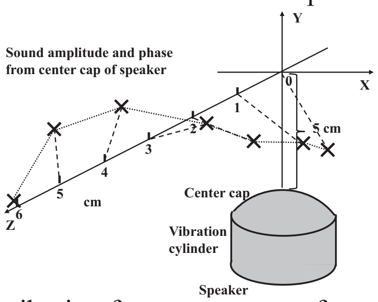


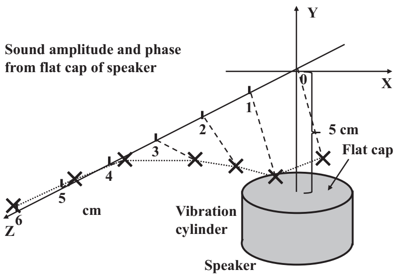
Fig. 3 Cross-sectional view of magnet-coil speaker.



(a) Sound distribution from full speaker.



(b) Distribution from center cap of speaker.



(c) Distribution from flat cap of speaker.
Fig. 4 Amplitude and phases of excited sound at 5-cm height from speaker (f=8 kHz).

4. Investigation of conventional sound devices

4.1 Examination on speaker mechanism

An examined speaker is shown in Fig. 3. It has not only a horn but also convex center cap to excite sounds. Output power is up to 10 W with internal impedance of 8 Ω. So, Vrms = 9 V is enough to obtain 10 W.

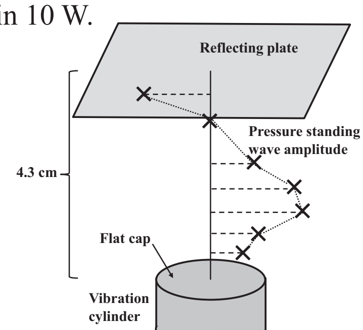


Fig. 5 Fundamental experiment to measure pressure standing wave between flat cap and reflecting plane (f=8 kHz).

4.2 Fundamental experiments using flat cap speaker

Measured amplitude and phase distributions of excited sounds at 8 kHz are shown in Fig. 4, which is the most important point to achieve coherent standing wave. Distributions at 5-cm height from a full speaker are shown in Fig. 5(a), while those of only a center cap are in Fig. 5(b). Those of a flat cap modified from the center cap are shown in Fig. 5(c). The preceding two's have large changes in both amplitudes and phases at 3-mm$^{\phi}$ area, while the last has almost uniform characteristics there.

We did a fundamental experiment using Fig. 4(c)'s flat cap speaker. As shown in Fig. 5, a reflecting plane is placed at 4.3-cm height from the speaker. Measured pressure standing wave amplitudes are also shown in the figure. They agree well to Fig. 1(b)'s middle simulation results, since λ=4.25 cm at 8 kHz.

5. Conclusion

We have examined conventional sound systems to check feasibility of replacing Langevin transducers. We will levitate particles based on these fundamental examinations next.

References

1. M. A. B. Andrade, et al, IEEE Trans. on UFFC, Vol. 57, No. 2, pp.460-479, 2010.