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Industrial Ultrasonic Levitation Machine Considering Conveyance – Experimental and Simulation Investigation of Conventional Sound Systems –

搬送系を考慮した産業用超音波浮揚装置 –通常音響装置による可能性の検討 –

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1. Introduction

Meissner effect is the most popular phenomenon to levitate magnets over supper conductive materials. However, its application is limited to specific area due to the requirement of extremely low temperature environment. On the contrary, ultrasonic levitation can be applied to any material in the air and room-temperature environment. During recent 20 years, many papers about levitations were published. However the most papers have focused on physical issues. Industrial applications of this technology have not been discussed so lively. Only in the Space Lab. of the Space Shuttle project, this technology has been used to keep experimental material fixed in a chamber. There are a lot of demands to use such phenomena in industrial fields. However, today's levitation instruments limit their applications to very specialized requirements. Because Langevin transducers, whose sizes are large, are used to excite high power ultrasonic waves of about 130 dB.

According to our fundamental experiments, levitation has been observed when the input DC power to Langevin transducer reaches several watts. However we can easily obtain magnetic-coli loud speakers which have over 10 W recently. In this paper, we did experiments of ultrasonic levitation using Langevin transducer at 20.5 kHz first. Using COMSOL simulator, sound pressure distributions within Fabry-Perot resonator were calculated. We also measured impedance characteristics of Langevin transducer. Based on the fundamental experiments and simulation and impedance, we developed a vibrating circular flat plate at around 20 kHz. Magnetic-coil mechanism was used, while the spring constant was reduced greatly compared with speaker. Almost same impedance was obtained, which shows the potentiality of new industrial levitation machine using the speaker technologies. A new conveyance mechanism is also investigated.

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2. Experimental ultrasonic levitation using Langevin transducer

We can check many papers about ultrasonic levitations nowadays. Mechanical amplifiers with half wavelength attached to Langevin transducer have been used to increase amplitude of vibrations. We used flat surface of Langevin transducer to excite ultrasonic wave without mechanical amplifier. Because we will replace Langevin transducer with vibrating plate driven by magnetic technology. As shown in Fig. 1, one to three spherical materials could be levitated at 20.5 kHz in the experiment. Input DC power fluctuates from several W to ten and several W, whose reasons are not clear now.

Fig. 1 Experimental results of ultrasonic levitation using Langevin transducer at 20.5 kHz.

3. COMSOL simulation for ultrasonic levitation using Langevin transducer

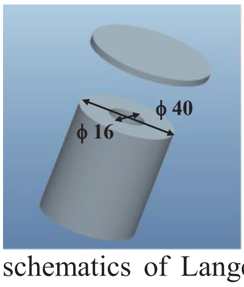
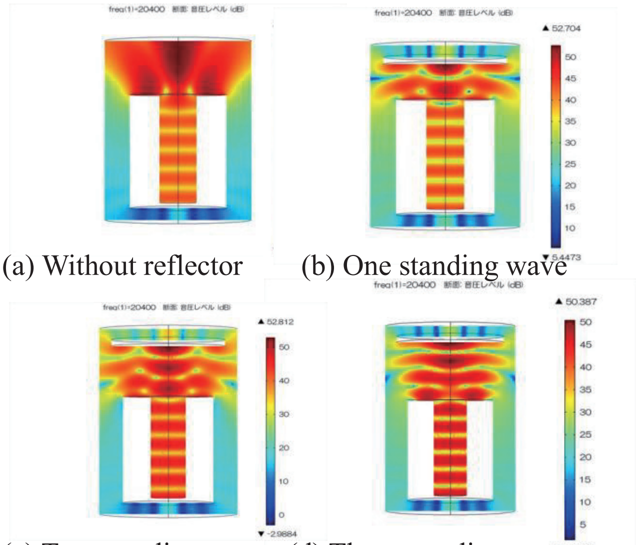


Fig. 2 Pro/E schematics of Langevin transducer and reflector for COMSOL simulation

In order to investigate levitation theoretically, we simulated Fig. 1's phenomena



(a) Without reflector (b) One standing wave

(c) Two standing waves (d) Three standing waves

Fig. 3 Sound pressure distributions at 20.5 kHz by COMSOL. Standing waves depend on distance between transducer and reflector.

using COMSOL simulator. Langevin transducer and a reflector are schematized by Pro/E shown in Fig. 2. Basic radiation patters without a reflector are shown in Fig. 3(a), while one to three standing wave patterns between transducer and reflector are shown in Fig. 3(b) to (d).

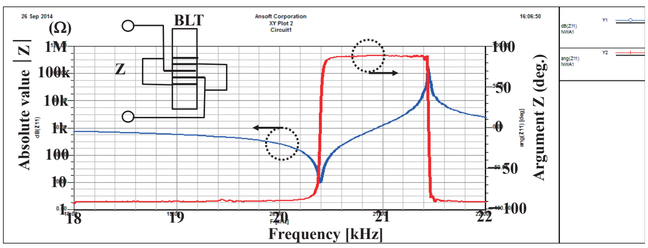


Fig. 4 Impedance characteristics of Langevin transducer. Driving frequency is set to 20.4 – 20.5 kHz, and impedance is 10-100 Ω.

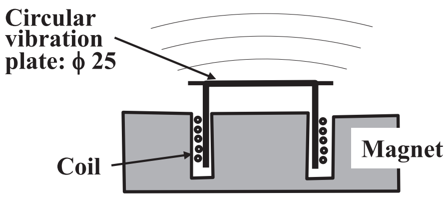


Fig. 5 Experimental flat circular vibrating plate driven by conventional magnet-coil equipment.

4. Comparison between impedance of Langevin and speaker-based transducers

We measured impedance characteristics of Langevin transducer. The transducer is driven at near resonant frequency. Impedance of 10 to 100 Ω at driven frequency of 20.4 to 20.5 kHz is obtained as shown in Fig. 4. For comparison, we made a speaker-based vibrating plate driven by magnetic coil with greatly reduced spring constant (Fig. 5). Impedance characteristics matched with L and C show the possibility of replacement, because similar impedance, i.e. about 50 Ω, is obtained as shown in Fig. 6..

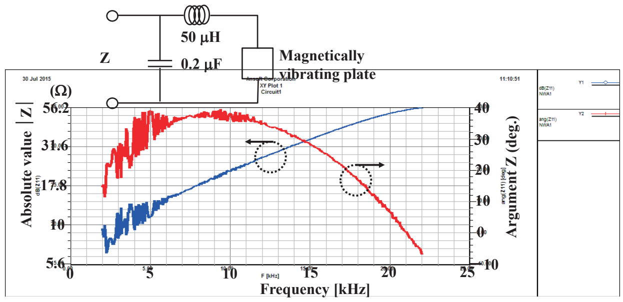


Fig. 6 Impedance characteristics of Fig. 5's magnetically vibrating plate. Introducing 50 μH and 0.2 μF as matching circuits, almost 50-Ω pure resistance can be obtained at 20 kHz.

5. Investigation on levitation system with conveyance

The target of this development is an industrial levitation machine with conveyance method. When we achieve the levitation machine driven by conventional sound technique, we will add transportation mechanism using air to convey materials from inlets to outlet as shown in Fig. 7.

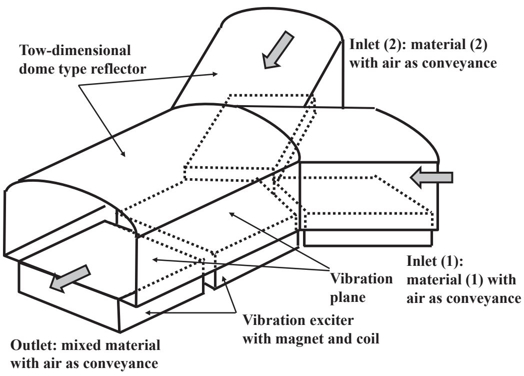


Fig. 7 Industrial ultrasonic levitation machine using conventional sound system and air as conveyance method.

6. Conclusion

We investigated the possibility of levitation using conventional sound system. Experiments, simulation and machine proposal were presented.

References

1. T. Ando and M. Hikita, in Proc. of USE Vol. 35, pp.295-296, 2014.