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Study on Three-Port Ultrasonic Levitation Machine with Conveyance Technique

搬送手段を有する 3 ポート超音波浮揚装置の研究–

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1. Introduction

Levitations have been interesting phenomena using several media, such as magnetic, ultrasonic and electrostatic fields. Meissner effect is the most popular phenomenon to levitate magnets over supper conductive materials. Similar technology has been already used in linear motor systems. 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 ultrasonic levitations have been published. However the almost all 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. That is because (1) sizes of Langevin transducers are large, and (2) transportation mechanism with inlets and outlets have not been discussed.

It has been reported that high power ultrasonic waves over 130 dB are necessary to levitate materials. From our fundamental experiments, levitation can be observed when input DC power to the driver circuit of Langevin transducer reaches several watts. Moreover we can easily obtain magnetic-coli loud speakers which have over 10 W recently. As shown in Fig. 1, our final target is achieving an industrial levitation machine which has inlets and outlets with conveyance mechanism between them. High power ultrasonic waves will be generated by conventional magnet and coil techniques, which can reduce both size and cost of the machine. Conveyance method of levitated materials will be achieved by air flow trapped within mesh guide as shown in the figure.

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In this paper, to achieve three-port levitation machine with two inlets and one outlet we did fundamental experiments and COMSOL simulation. Three Langevin transducers at 20.5 kHz are exited synchronously and mesh guide for air flow is fixed between the reflector and transducers. COMSOL simulator is used to obtain sound pressure distributions within three-parallel Fabry-Perot resonator.

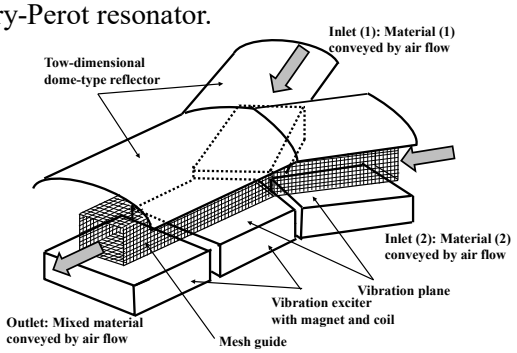
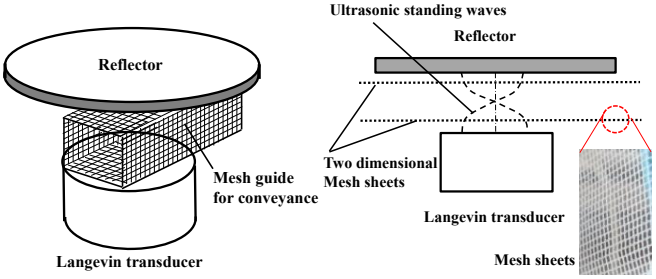


Fig. 1 Target of three-port levitation machine. Conveyance by air flow trapped within mesh guide and conventional sound system are used.

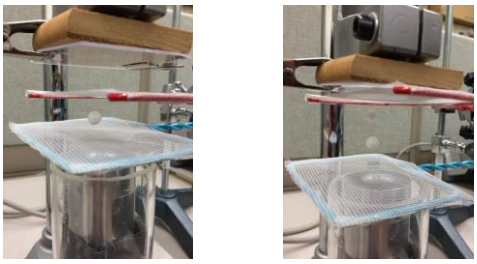
2. Investigation of mesh guide for conveyance

We first checked influence of the mesh guide to ultrasonic waves to levitate materials. As shown in Fig. 2(a) mesh guide has three-dimensional configuration. However to clarify effects of mesh to ultrasonic standing waves experimentally and simulate disturbed ultrasonic fields due to mesh we introduced two-dimensional structure as shown in Fig. 2(b).



(a) Mesh guide to convey materials by air flow (b) Two-dimensional mesh guide (mesh sheet) to check experimentally and simulate

Fig. 2 Model of mesh guide to study and simulate. Langevin transducer was used in experiment.



(a) One standing wave (b) Two standing waves
Fig. 3 Experimental check of effects of mesh sheets for ultrasonic levitation.

In the experiment, we used Langevin transducer to generate 20.5 kHz standing waves between the transducer and reflector as shown in Fig. 3. Mesh sheets seem to have almost no effects for both one (Fig. (a)) and two standing waves (Fig. (b)). But it is necessary to make clear the field disturbances due to mesh sheets using COMSOL.

3. Basic experiment for three-port levitation machine

In order to check the feasibility of three-port levitation machine, we did fundamental experiment using three Langevin transducers. They are arranged apexes of equilateral triangle. Each Langevin transducer can be driven independently by supplying AC voltages with different amplitude. However they are all synchronized to same frequency and phase. Two of them are assigned to inlet ports, while the remaining one to outlet port. Finally we will change each driving voltage level and standing wave form to achieve the best condition for levitation and transportation of materials.

Experimental setup is shown in Fig. 4. A function generator provides 20.5 kHz pulses to three modules which consist of branch circuits and power switches. DC power source is supplied to each module to generate high amplitude driving voltage to each Langevin transducer. By changing the level of each DC power source it is possible to obtain the required driving voltage level for each transducer. As shown in Fig. 5, three materials are levitated, which shows the possibility of three-port levitation machine.

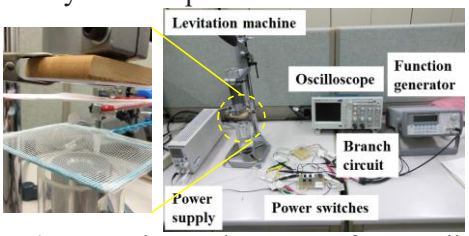


Fig. 4 Experimental setup for preliminary three-port levitation machine.

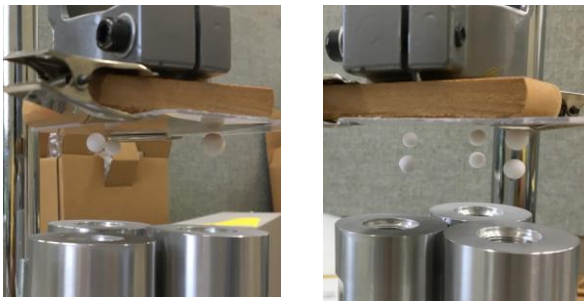
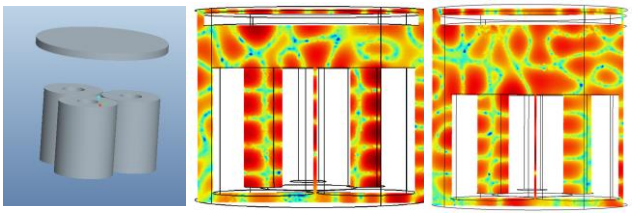


Fig. 5 Experimental results of preliminary three-port levitation machine. Each Langevin transducer can be driven independently.

4. COMSOL simulation for three-port levitation machine

COMSOL simulator is one of the most powerful simulation tools. In three-port machine ultrasonic waves generated from several exciters such as Langevin transducer and magnet-coil transducers interact one another between exciters and reflector. It is important to make clear the mixed ultrasonic fields to design three-port machine with uniform standing waves along the guides. We simulated the ultrasonic fields corresponding to experimental models of Fig. 5. Examples of simulation are shown in Fig. 6, which will be very useful to achieve three-port levitation machine with conveyance method.



(a) Pro/E schematics of three Langevin transducers and ref. (b) One and Two standing waves between transducers and reflector
Fig. 6 COMSOL simulation results of sound pressure distributions corresponding to Fig. 5's experiment.

5. Conclusion

We have proposed ultrasonic three-port levitation machine with conveyance method for industrial use. Transportation by air flow in mesh guide and possibility of three-port structure are examined with experiment and simulation.

References

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2. M. Yamamoto and M. Hikita, in Proc. of USE Vol. 36, 2015.