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A MHz Power Ultrasonic System using Parabolic Boundary Reflector
放物面境界を反射鏡とした MHz 帯パワー超音波振動系の検討

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1. Introduction

A high-power MHz ultrasound system has been required for recent decades. In the field of ultrasonic welding, MHz high power ultrasonic waves enable precise welding and are potentially applicable to crystalline resin welding. However, in general, commercially used bolt-clamped Langevin transducers are difficult to excite <400 kHz. Therefore, MHz ultrasonic systems have been studied, such as surface-acoustic-wave device using piezoelectric substrate[1], concave focusing transducer[2], and focusing by acoustic metal lens [3]: nevertheless some problems have not been resolved, such as liquid required for focusing, or production is difficult. Easy use and easy production MHz ultrasound system is needed.

In this work, we fabricate a prototype of a metal-based acoustic reflector with metal-air parabolic boundaries. It is solid-based vibration system. In order to explore an optimal shape, finite element analysis (FEA) was carried out.

2. Parabolic-Boundary Reflector (PBR)

Schematic structure of the P.B. reflector [4] is shown in **Fig. 1**. Longitudinal waves excited on piezo-element are reflected by the metal-air parabolic boundary, and are focused to the output plane. All the sound ~~ray~~ paths have the identical length. There are two crucial loss factors of this reflector: (1), acoustic wave mode conversion ~~loss~~ at the boundary reflection; (2), propagation loss in the metal.

3. Shape Optimization by FEA Simulation

We created a two-dimensional model. The model parameters are shown in **Table 1**. Changing three of the parameters, window angle θ_w, focal length a, and a variable for adjustment of the propagation distance d for 1 mm interval to exploring a combination to maximize the vibration amplitude at the focused point on output surface. Model material is aluminum which has a low acoustic propagation loss (-0.19 dB/cm), and the PZT vibration frequency set to 1 MHz with uniform vibration on the exciting surface. Result at both ends of the output surface excluded.

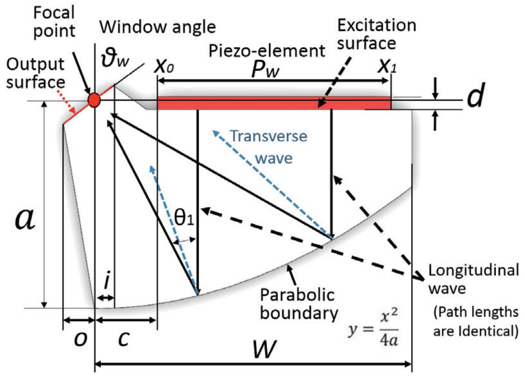

Fig. 1 Parabolic boundary reflector.

Table1 Parameters for the simulation.

Parameters	Values
α	**20~70** [mm]
ϑ_w	**20~100** [deg]
d	**-3~3** [mm]
o	3 [mm]
i	2.5 [mm]
c	3 [mm]
P_w	45 [mm]
W	50 [mm]

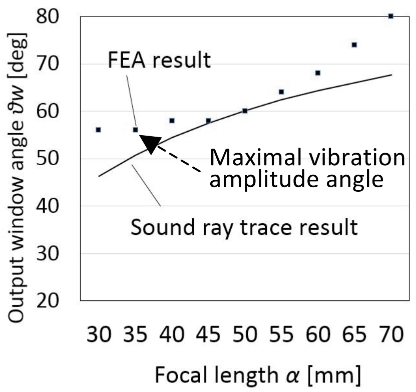

Fig. 2 Simulated window angle vs focal length.

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4. Simulation Result

Results for the optimal window angle *vs* focal length obtained by the sound ray tracing method and FEA simulation are shown in **Fig. 2**. There is a tendency that the FEA-simulated optimal angles become deeper than the sound ray trace methods. Both show the same results at a = 50 mm.

Results for the focal length *vs* vibration amplitude on the output surface is shown in **Fig. 3**. Maximal vibration amplitude is at focal length a = 35 mm in this range. The optimal focal length is 37 mm by the sound ray tracing method. Both results turned out almost the same.

Fig. 5 shows the tendency that the output vibration amplitude is sensitive to the propagation distance. If propagation distance is not optimal, the vibration amplitude is drastically decreasing.

5. Experimental Result

As shown in **Fig. 6**, we made a prototype P.B. reflector made of duralumin (A5052). Parameters were a = 35 mm, $\theta_{\rm w}$ = 57 degrees, d = 0 mm, being based on the simulated optimal shape. The body thickness is 50 mm. Piezoelectric (PZT) elements (15x8x2 mm) were adhered on the excitation surface.

Experimental result indicates that the output has been significantly increased compared with the previously reported one[4]. Maximal vibration amplitude was 23 nm and the vibration velocity was 160 mm/s at 70 V and 1.17 MHz. Making use of the high vibration amplitude, we have succeeded in butt connection welding of plastic optical fibers using the optimized reflector.

6. Conclusion

According to the results obtained by the FEA simulation, the maximal vibration amplitude appeared at the output surface when the focal length, the window angle and the propagation distance were 35 mm, 57 degrees and 0 mm. Vibration amplitude is sensitive to the variation in the propagation distance. These are approximately similar to those obtained by sound ray method, where the wave nature is not taken into account.

References

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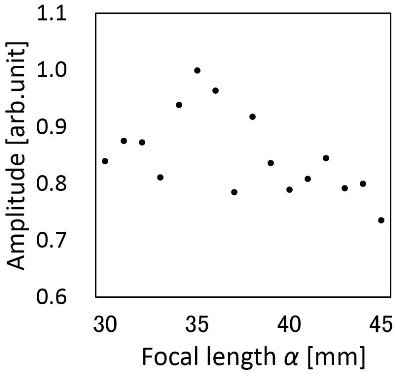

Fig.3 Simulated amplitude *vs* focal length.

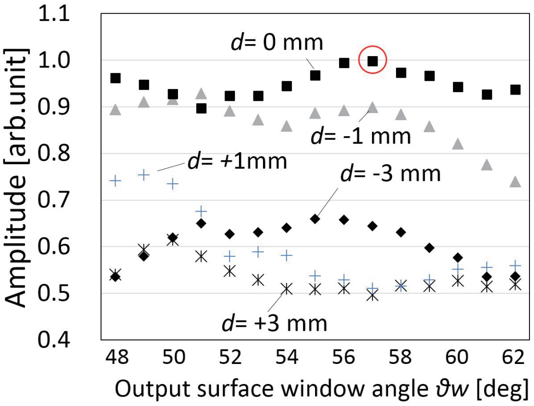

Fig. 4 Simulated amplitudes for different wave propagation length d *(a = 35mm)*.

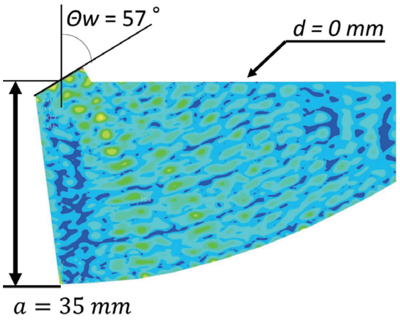

Fig. 5 Optimized shape by FEA.

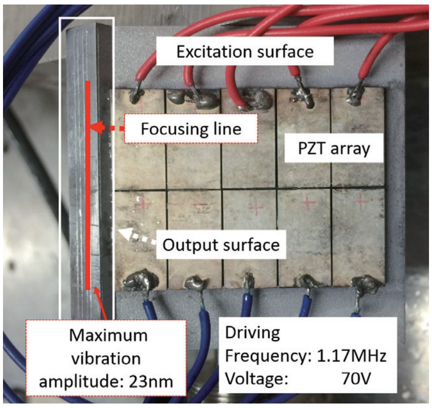

Fig. 6 Optimal shape prototype P.B. reflector.