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Examination on a High Power Aerial Ultrasonic Generator Using Cross Type Direction Change for Longitudinal Vibrations.
縦振動の十字型方向変換を利用した空中超音波音源の検討

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1. Introduction

The most Practical source of aerial ultrasonic energy having a large capacity comprises an ultrasonic vibration transducer equipped with an amplitude-increasing horn, a vibration transmission rod mounted at the tip of the horn, and a striped-mode flexural vibrating plate connected to the transmission rod.[1)] This report proposes the method of driving multiple vibrating plates by using the cross type vibration transmission rod assembly to increase[2)] the output from an ultrasonic sound source. To establish the design method for forming the multistage of cross type vibration transmission rod assembly, we made vibration simulations and trial-manufactured the multistage of cross type vibration transmission rod assembly. As a result, we found that multiple vibrating plates could be excited by using the multistage of cross vibration transmission rod assembly.

2. Construction of Cross Type Transmission Rod

Figure 1 shows the schematic views showing the construction of the cross type transmission rod assembly proposed by us, and the ultrasonic source of longitudinal vibrations combined with the transmission rod assembly. The cross type transmission rod assembly is based on the principle of a multi-dimensional transmission medium[3)], and can divide the longitudinal vibrations produced by using ultrasonic waves into those in the right and left perpendicular directions, as well as vertical direction. As shown in the figure, each 1/2-wave length resonance transmission rod has two cuts formed symmetrically about the longitudinal axis of the rod on the central sides of the rod. A 1/4-wave length resonance transmission rod is connected to each of the two cut parts by using the screws. Screws are attached to the ends of the transmission rods SL1 and SR1 to mount vibrating plates on the rod ends.

3. Experiments

3.1 Considerations on the lengths of vibration transmission rods

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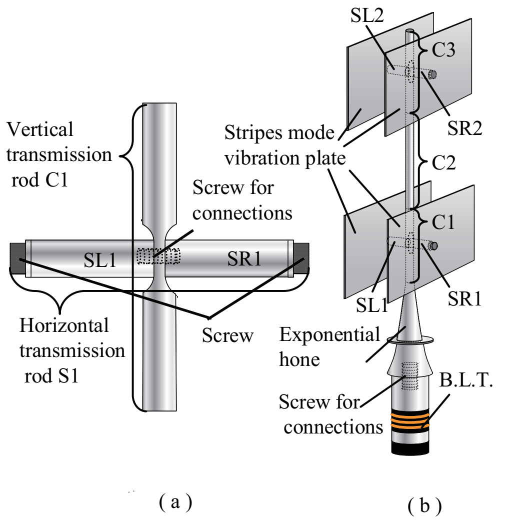

Fig. 1 Experimental device

At first, we made vibration simulations on 2 stages of cross type vibration transmission rod assembly as shown in Fig. 1 by using the vibration analysis software (ANSYS). Here, duralumin rods with a diameter of 12mm were used as vibration transmission rods. Based on the previous considerations, the half wavelength of the vibration transmission rods (C2) in non-cut state was set at 128mm, while that of the vibration transmission rods (C1 and C3) in cut state as shown in Fig. 1 (a), was set at 100mm[4),5)]. In addition, the horizontal transmission rods SL1 and SR1 were without any screws when the vibration was analyzed, and the lengths of the horizontal transmission rods S1 and S2 were set at 128mm. All the vibration transmission rods were connected with each other by the stainless steel screws with a diameter of 6mm.

Based on the results of the vibration analysis, we trial-manufactured vibration transmission rods. The resonance frequency obtained by using these vibration transmission rods were 20.00 kHz, or different from that presented by our simulation. Therefore, we varied the length of the half wavelength resonance vibration transmission rod (C2) connecting to 2 cross type vibration transmission rod assembly. As a result, the desired resonance frequency (20.4 kHz) was obtained at the rod length of 116mm.

Then, we analyzed the vibrations to determine the lengths of the horizontal transmission rods S1 and S2. **Figure 2** shows the results. The figure indicates that the vertical and horizontal transmission rods presented the symmetrical vibration characteristics.

3.2 Test manufacture of 2 stages of cross type vibration transmission rod

Based on the results as described above, we trial-manufactured 2 stage of cross type vibration transmission rod assembly. Then, we determined the vibration amplitude characteristics by varying the lengths of the horizontal transmission rods, as shown in Fig. 1. It should be noted that the lengths of the horizontal transmission rods S1 and S2 were changed from 128mm into 120mm, because stainless screws (as shown in Fig. 1) were used to mount vibrating plates on the horizontal transmission rods. **Fiure 3** shows the results obtained, and presents the vibration characteristics similar to those obtained by the vibration analysis. If the lengths of the horizontal vibration transmission rods were 108mm or less, any good vibration was not obtained. This suggests that it will be necessary to design each vibration transmission rod on condition that the vibration amplitude of the horizontal vibration transmission rods will not be greater than that of the vertical transmission rods.

3.3 Vibration characteristics of vibration transmission rods connected with vibrating plates

Based on the above-described results, the length of the horizontal transmission rods (S1 and S2) was set at 110mm, and 4 stripe-mode vibrating plates (at the frequency of 20.41 kHz and with the sizes of 111mm × 296mm × 2mm) were mounted on the end of each vibration transmission rod, as shown in Fig. 1(b). **Figure 4** shows the vibration characteristic at the end face of each vibration transmission rod. The vibration characteristic shows that the vibration amplitudes vary by the power of 1/2 of the supplied electric power depending on the supplied electric power. For the electric power of 100 W supplied to the ultrasonic source, the vibration amplitude at the center of each vibrating plate was about 8 μm. Thus, it was confirmed that the ultrasonic source could be well driven.

4. Conclusions

To develop the ultrasonic generator that may produce a great capacity of aerial ultrasonic wave energy, we trial-manufactured 2 stages of cross type vibration transmission rod assembly by using the vibration simulation and the experimental results. As a result, it was found that good longitudinal vibrations could be produced at each of 5 end faces of the cross type vibration transmission rod assembly. If 4 stripe-mode vibrating plates were mounted on the vibration transmission rods, it was also confirmed that good longitudinal vibrations could be produced.

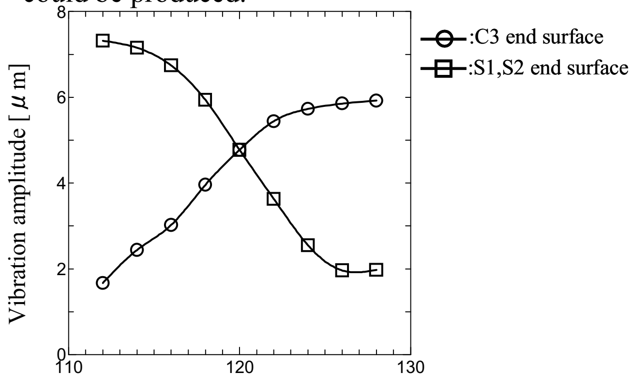

Fig.2 Vibration amplitude VS length S1 ,S2 (Analyzed)

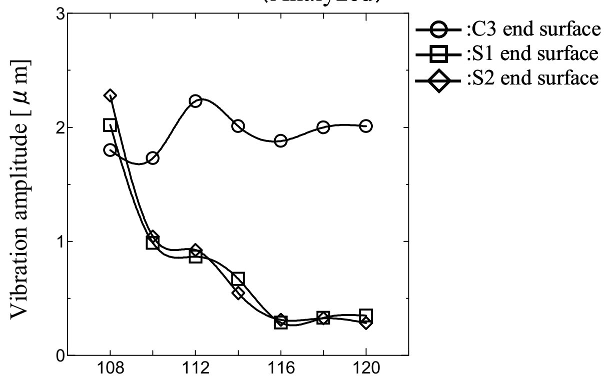

Fig. 3 Vibration amplitude VS length S1 ,S2 (Experimental)

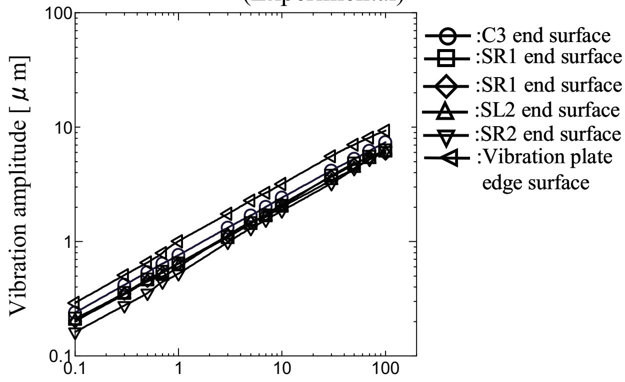

Fig. 4 Longitudinal vibration amplitude distributions of vibration transmission rods (SL1,SR1,SL1,SR2,C3,Vibration plate)

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