SHORT NOTE

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High efficiency ultrasonic sound source in air

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Y. Sasaki, K. Matsuzawa, M. Ochi & T. Hasegawa
Department of Physics, Faculty of Science, Ehime University, Matsuyama, 790 Japan
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Introduction

It is well known that a fairly effective radiation of acoustic power in air is brought about by the use of a thin metallic plate vibrating in a flexural mode at an ultrasonic frequency.[1,2] Previously, sound sources having 80% efficiency in air were reported by one of the authors, but their construction was not so strong.[3,4] Therefore, some improvements have been made. The design and performance of a new model of a ruggedly built sound source having high efficiency in air and also the intense sound field produced by the new model are described in this paper.

Construction

The construction of a sound source of the new model is shown in Fig. 1. The vibrator is a bolt-clamped Langevin-type PZT transducer for use at 20 kHz (NGK Spark Plug Co., Ltd., D–4420A). A horn was attached to the vibrator with epoxy adhesive (Araldite). The horn is made of titanium alloy (Kobe Steel, Ltd., KS–130AV). When the horn was turned in a lathe, the end of the 10-mm-diam rod was cut to a 5-mm-diam screw. The ratio of the cross-sectional areas of the step horn is $(46/10)^2=21$. A 1-mm-thick duralumin diaphragm was attached to the horn with an iron nut. It may be noted that, in the old model,[3,4] a magnetostrictive vibrator and a duralumin horn were used and a diaphragm was attached to the horn with a 3-mm-diam bolt.

The sound source was supported by soft plastic foam which touched the vibrator and the 46-mm-diam rod of the horn.

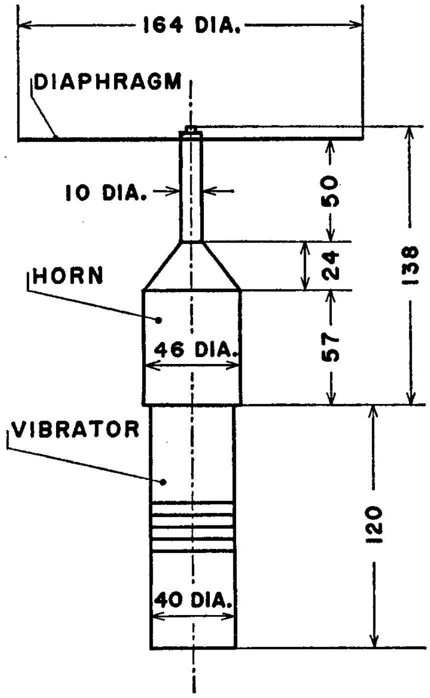

Fig. 1 Construction of the sound source (in mm).

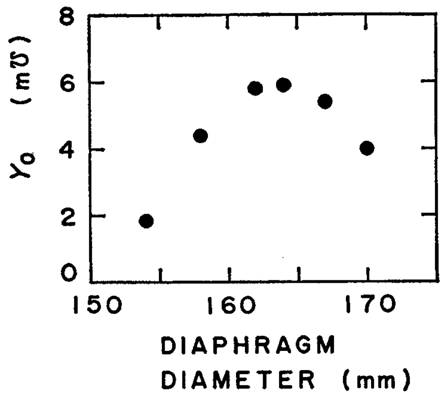

Fig. 2 Diameter Y_0 of motional admittance circle in air as a function of diameter of diaphragm with seven nodal circles.

Characteristics

The free admittance loci of the sound source at low powers (in the order of 10^{-2} W) were plotted by means of a free immitance meter (Cho-onpa Kogyo Co., Ltd., UIM–5) and an x–y recorder. Let Y_0 and Y_{00} be the diameter of the motional admittance circle when the sound source operates in air and that when in a vacuum, respectively. As shown in Fig. 2, Y_0 was obtained as a function of diaphragm diameter; each diaphragm had seven nodal circles. For the maximum Y_0, it is inferred that the resonance frequency of the vibrator-horn-nut system is almost equal to that of the diaphragm driven by the system. Accordingly, the 164-mm-

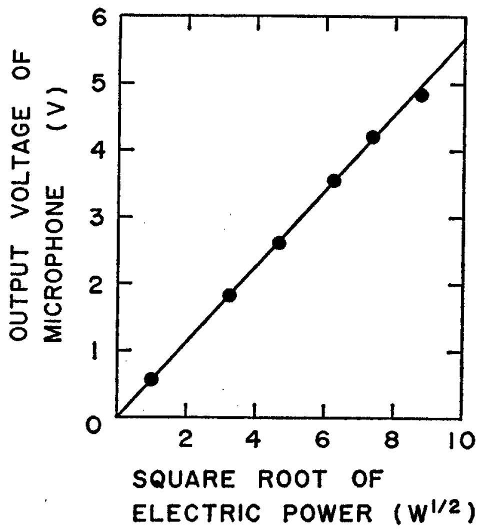

Fig. 3 Relation between output voltage of a microphone and square root of input electric power applied to the sound source with the 164-mm-diam diaphragm.

diam diaphragm was selected as the only one to be examined in detail, as described in the following.

From the free admittance loci, it is found that the resonance frequency is 20.0 kHz, Q is 1.2×10^3 in air and 1×10^4 in a vacuum, $Y_0=5.9$ m℧, $Y_{00}=44$ m℧, and the separation between the ordinate of the admittance plane and the circle of the locus in air is about 0.01 m℧. As is well known, the electroacoustic conversion efficiency at the resonance frequency is given by $(Y_0/G)\cdot(1-Y_0/Y_{00})$, where G is the free conductance in air at resonance.[5] Thus, the efficiency at low powers is $(5.90/5.91)\cdot(1-5.9/44)=0.86$.

The sound pressure was measured with a 1/8 in. microphone (Brüel and Kjaer, Type 4138). The sound pressure along the center axis of the diaphragm has a single peak, which is caused by the convergence as discussed by one of the authors previously.[4] The microphone was fixed at the peak point, i.e., at a distance of 25 mm from the diaphragm, and the sound source was supplied with electric powers ranging from 1 to 80 W. As shown in Fig. 3, the output voltage of the microphone is proportional to the square root of the input electric power. On the basis of the microphone sensitivity listed in its calibration chart, it is found that the sound pressure level is 170 dB (i.e., sound pressure 6.3×10^3 Pa) for an electric power of only 40 W.

Additional Experiments

Other three sound sources of the new model were made. Their construction is the same as shown in Fig. 1 except that the dimensions of the horns and accordingly the diameter of the diaphragms are somewhat different. Their efficiency is 84 to 90% and their sound pressure as a function of electric power is similar to that shown in Fig. 3.

References

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