## 3. Design and fabrication of a short column type power accumulator[3]

### 3.1 A way of design of the power accumulator

From the above equations, we obtain a process of power accumulator design as follows.

step_1) Determine the driving frequency and the material of accumulator. Thus the value of $k_0$ and the value of $\nu$ are determined.

step_2) Determine the column shape l/a and the mode number m. From table 1, the value of $\alpha_m$ is determined.

step_3) Find $k_0 l$ for given l/a by Fig.2. Thus the length l is determined.

step_4) Modify the shape of the end surfaces to a regular polygon, because the driving transducers is adhesive attached on the side surface of the power accumulator. The modification should be carried out under the condition that the area of the end surfaces is unchanged.

When w denotes a side length of the polygon, 2l and w should be long enough for adhering.

### 3.2 Fabrication of a power accumulator

To make the circumference of the column long, that is, to increase the number of driving transducers, we chose the 2nd mode for the radial vibration (i.e., m=2; thus $\alpha_m$=5.40). Moreover, we determined l/a=0.2 where the radial vibration dominates, because the side surfaces are driven by the driving transducers. Figure 3 shows a power accumulator for trial purposes. The theoretical resonance frequency is 136kHz and the material is duralumin. The shape of the end surfaces is a regular dodecagon. The twelve piezoelectric transducers are used to drive, and the dimension of each transducer is 10x10x10mm. Accumulated power is picked up from an end surface by using a horn.

## 4. Experiment

### 4.1 Confirmation of the vibration mode

Figures 4(a) and (b) show the experimental results of the displacement distribution measured by a laser doppler system. This system can measure vibrating velocity which is in proportion to displacement. To drive the accumulator, a transducer has been mounted on the horn. The value of resonance frequency was changed to 141.82kHz; This change was probably caused by shape modification.

As shown in Figs. 4(a) and (b), there is good agreement between the theoretical result and the experimental results. Longitudinal displacement $U_z$ and radial displacement $U_r$ are given by the following equations[2].

$$\begin{cases} U_z = U_{z0}\{J_0(pk_r r) - (1-\nu)J_1(pk_r r)/pk_r r\}\sin(k_z z) & \text{(7a)} \\ U_r = U_{r0}\cos(qk_z z)J_1(k_r r) & \text{(7b)} \end{cases}$$

where $U_{z0}$ denotes the axial displacement at the center of the end surface of the column, while $U_{r0}$ gives the radial displacement at the center of the side surface. p and q are a function of l/a and must be determined from measured displacement distributions. In Fig.4, it was determined that p=1 and q=0.65.

### 4.2 Confirmation of apportionment of acoustic load

Here, we have adhesive attached each transducer to each side surface with epoxy resin, and confirmed that the each transducer apportioned an acoustic load. As shown in Fig.5(a), we have measured the input current $I_i$ (i=1,2,···,12) under the transducers have been driven in parallel.

From Fig.5(b), we can confirm that the accumulator vibrates in the desired mode, and each transducer apportioned an acoustic load. The value of the resonance frequency was changed to 140.74kHz by adhering.

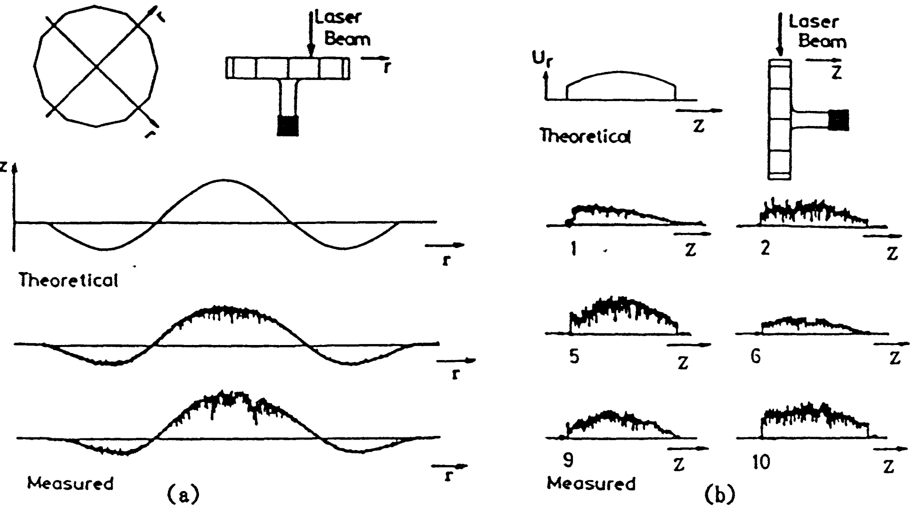


Fig.4 Displacement distributions on the (a)end surface and (b)side surface. Each number shown in (b) denotes the surface number (see Fig.3).

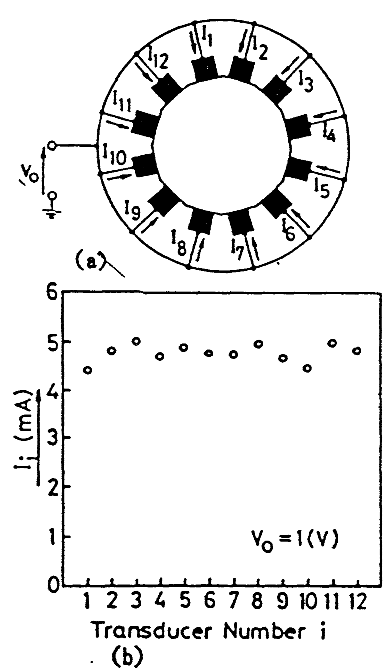


Fig.5 Apportionment of acoustic load. Mark ■ denotes a transducer.

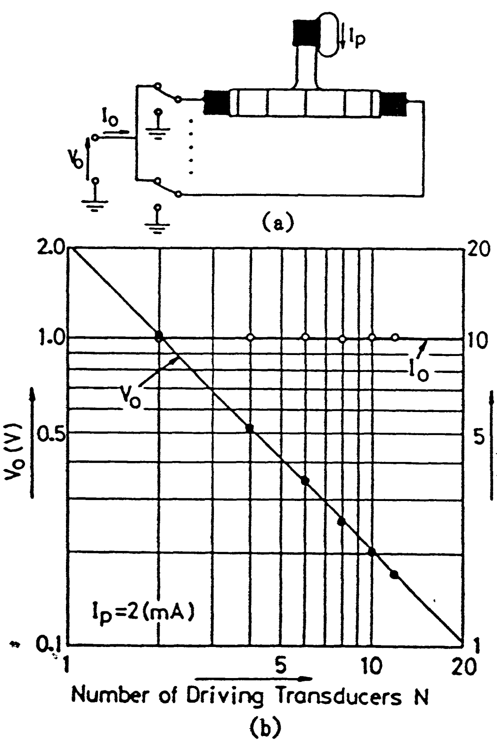


Fig.8 Accumulation of acoustic power. Solid lines are to guide the reader's eye.

### 4.3 Confirmation of the accumulation of acoustic power

Here, we confirm the acoustic power accumulation by the following way (see Fig.6(a)). That is, the supplied voltage $V_0$ is measured as a function of the number of driving transducers under the vibrating velocity of the end of the horn is kept constant. These transducers are driven in parallel. Under the condition, if supplied current $I_0$ is kept constant and $V_0$ is in inverse proportion to the number of driving transducers, then we will confirm accumulation of acoustic power.

Figure 6(b) shows the result. During this measurement, we have monitored the vibrating velocity by a transducer mounted on the end surface of the horn. Moreover, each of the transducers has paired with one another which is on the opposite side. The number of driving transducers has changed by one pair. From Fig.6(b), it is clear that the accumulator have accumulating acoustic power.

### 5. Conclusions

We have derived a way of design of a high frequency power accumulator using a short column type circular disk. Moreover, according to the way, we have fabricated a power accumulator by using 2nd mode vibration of the radial direction. From some measurements for the characteristics of the accumulator, we have confirmed that the accumulator have accumulating acoustic power.

### References

1) K.Itoh and E.Mori: Journal of Acoustical Society of Japan. Vol.25 No.5 (1973)307-314 [in Japanese]
2) E.Mori, K.Itoh and A.Imamura: Ultrasonic International '77 conference Proceedings (1977) 262-266
3) Y.Watanabe, Y.Tsuda and E.Mori: Reports of the 1987 Autumn Meeting of Acoust. Soc. Japan, Oct.(1987)717 [in Japanese]

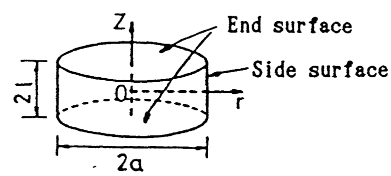


Fig.1 A short column.

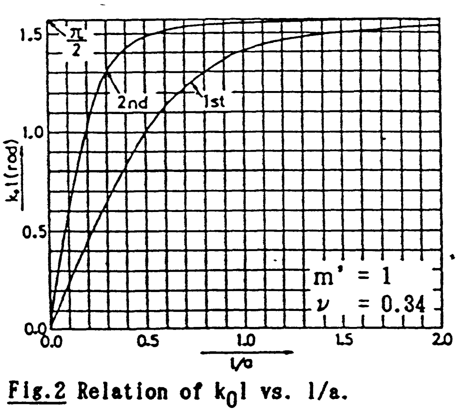


Fig.2 Relation of $k_0l$ vs. l/a.

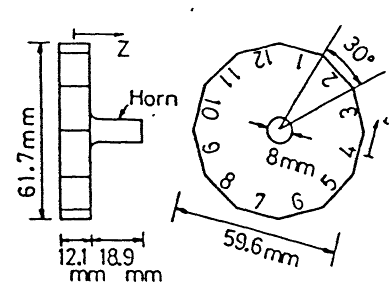


Fig.3 Fabricated power accumulator. Each number placed near each side line denotes surface number.

Table 1. Values of $\alpha_m$.

| material | Poisson's ratio $\nu$ | $\alpha_m$ | |
|---|---|---|---|
| | | m=1 | m=2 |
| steel | 0.28 | 2.04 | 5.38 |
| duralumin | 0.34 | 2.08 | 5.40 |