A Modular Transducer Exerting Acoustic Interaction For Low Frequency Project

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Abstract. The miniaturization of the low frequency, high-power transducer has becoming the hot spot in the transducers research. With the variety type of sonar's working frequency went below, the increasing demand for low-frequency performance of the underwater acoustic counter device. The conventional low-frequency transducer can't meet the demand for underwater acoustic counter device as their limited spatial arrangement. The flexural disc transducer with adjustable width can be arranged axially is very suitable for low-frequency device with limited size.

In this paper, we have introduced the configuration of the flexural disc assembled system (FDAS) and the concept of interaction radiation also been discussed. The prototype of the FDAS has been shown and some testing data also been published.

Introduction

The FDAS is comprised of numbers of flexural disc transducers (benders) arranged axially. By exploiting the interaction between the closely-packed underwater sound projector, we can reduce the resonance frequency and expand the bandwidth without dimension increasing. This type of transducer is very suitable for daggling acoustic device.

Bender description

The foreign have developed a novel flexural disc transducer based on the triple and double plates. The two plates is built by putting piezoelectric ceramics and metal disc bonded together, then putting the two plates connected together through the thin ring. The ceramics are positioned on the outside of the metal discs. The thin ring is positioned in the middle of the two plates. The air filled gap is also made between the double plates. The basic working concept for this type of transducer is that bending vibration of the metal driven by the radical contraction of the piezoelectric ceramics which project the acoustic wave. The air-filled gap plays a role of unmatching the impedance and improving the projection efficiency.

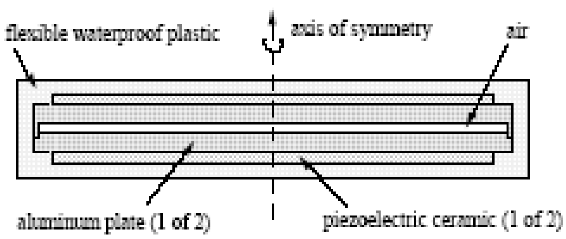

Fig.1 cross-sectional views of flexural disc transducer

Theory discussion

According to the superposition principle of linear acoustic, The acoutic pressure at any point should be equal to the sum of the acoutic pressure of each radiation field from the different acoustic source. In this paper, the simple analysis has been given. Supposing one FDAS is assembled by numbers of elements, and each elements are labeled as 1,2,3…n. Bender is equivalent to the piston motion wherein each points have the same velocity, the average velocity of u, so the total force F_1 on the projection plane of the 1st element is given in Eq.1:

$F_1=f_{11}+f_{12}+f_{13}+\cdots\cdots\cdots\cdots+f_{1n}=f_{11}+\sum_{s=2}^{n}(f_{1s})=Z_1\times\bar{u}_1$ (1)

f_{11}—represent the force of the element 1's radiation field acoustic pressure on its own plane

f_{12}—represent the force of the element 2's radiation field acoustic pressure on its own plane

…………………

f_{1n}—represent the force of the element n's radiation field acoustic pressure on its own plane

According to the definition of radiation impedance, the total radiation impedance of the element 1 is:

$Z_1=Z_{11}+\sum_{s=2}^{n}(Z_{s1})=Z_{11}+Z_r$ (2)

$Z_{11}=R_{11}+X_{11},X_{11}=(j\omega m_{11}-\frac{j}{\omega C_{11}})$. (3)

In Eq.3, C_{11} represent the capacitive reactance. m_{11} represent self-quality reactance of the element one and R_{11} represent self-radiation impedance of the element one. $Z_r=\sum_{s=2}^{n}(Z_{s1})=\sum_{s=2}^{n}(R_{s1}+X_{s1})$ is the sum of mutual radiation impedance by the other elements toward the element one. Because the closely-packed configuration of the FDAS and maximum separation distance between the bender is far smaller than the wavelength of the acoustic wave, so the value of equation is always positive. The single bender in the FDAS can be analogy to the equivalent circuit shown in Fig.2:

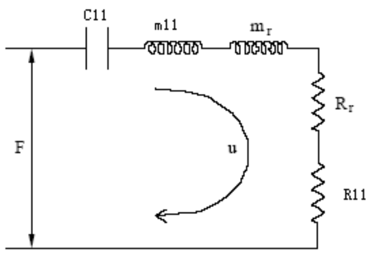

Fig.2 euivalent circuit for the FDAS

The resonant frequency of the element one can be derived in Eq.4:

$\omega_{res}=\sqrt{\frac{1}{(m_{11}+m_{r1})C_{11}}}$ (4)

The resonant frequency of the other elements can also be derived by the same method:

$\omega_n=\sqrt{\frac{1}{(m_{nn}+m_{rn})C_{nn}}}$ (5)

It can be reffered from Eq.5 that little spacing between the nearest benders and the value of m_{rn} is positive leading to the resonant frequency of a single bender is higher than the FDAS assembled by numvers of small benders.

Manufacture

We built the prototype of the FDAS shown in Fig.3 to verify the testing value with the theory. FDAS is comprised of eight benders arranged axially with uniform spacing, the distance between the closest center of the benders is given by 30mm. The size of the FDAS is 200mm and the weight of the FDAS is lower than 12kg in order to reduce the cavitate phenomenon.

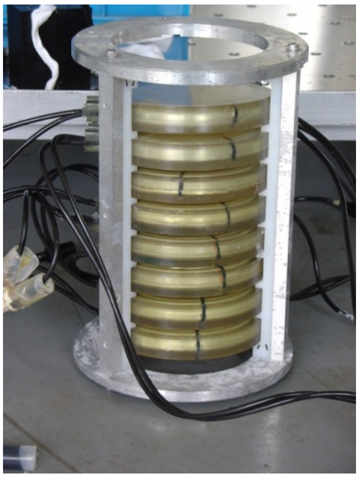

Fig.3 8-benders

Lake test results

We choose the Mogan-mountain Lake as the testing place. The Transmit Voltage Level and source level for both of the single bender and 8-benders have been tested. Finally, the endurance of this type of transducer has been tested.

The resonant frequency of the single bender is approximately at 1.1KHz while the peak TVR at 130dB. We follow the ultimate safety voltage 394Vrms/mm and add the maximum voltage to 1200Vrms to the transducer. Table 1shows the testing data:

Table 1 The results of single bender

Text frequency(Hz)	Driver voltage (Vrms)	TvR(dB)	SL(dB)
1100	100	132.7	172.7
1100	200	132.4	178.4
1100	400	131.9	183.9
1100	600	131.8	187.4
1100	1000	131.4	191.4
1100	1200	131.7	193.4

The resonant frequency of 8-bender array is approximately at 500Hz, and peak TVR is 138dB. Table 2 gives the testing data:

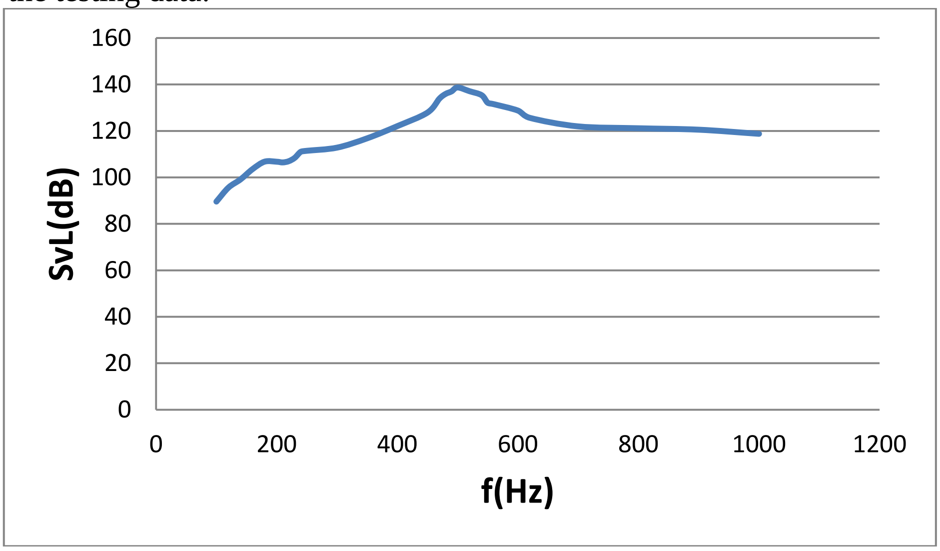

Figure4 TVR of 8-bender array

Table 2 The results of 8-bender array

Text frequency(Hz)	Driver voltage (Vrms)	TvR(dB)	SL(dB)
500	100	138.4	178.4
500	200	138.4	184.4
500	400	138.9	190.9
500	600	130.8	186.3

Because of the shallow depth of the water, the cavitate phenomenon is significantly strong and brought about the distortion as the voltage is added to 600Vrms. Since the limited conditions, we can't put the FDAS into the deeper water.

Summary

The radiation interaction can be used to change the radiation impedance of the transducer and thus reducing frequency and improving voltage level and bandwidth. In this paper, the FDAS assembled by close-packed benders can reduce the resonant frequency associated with improving the response. But also brings about the cavitate phenomenon.

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