

Research of decreasing the influence of coupling effect on High-frequency circular piston transducer

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Abstract. This paper analyzes the impact of coupling effect on the high-frequency circular piston transducer. Focuses on the impact of the direction and the transmission voltage response in the case of constant thickness and mutative diameter. Raised a new method for Circular piezoelectric wafer center opening that decreases the influence of coupling influence, and experimental study was operated. According to the method, Transducer prototype is developed and the influence of coupling influence is little. The resonant peak in the thickness direction is obvious. The new method has a good adaptability, it could be widely extended to the same type of transducer designing.

Introduction

Echo sounder is an important type of underwater acoustic navigation device, it can provide information on the location of the depth of the ship to ensure the safety of navigation. As an important component on the echo sounder, the high-frequency circular piston transducer is mounted on the bottom of ship and is accountable to launch vertically a frequency modulated pulse sonic to underwater.

In practice the high-frequency circular piston transducer is susceptible to coupling effect. Effect of the coupling can be eliminated by the cutting method. But the cutting methods exist shortcomings of more processes, resource-intensive and long-cycle. This paper will propose a method opening hole in the center of the circular ceramic wafers. This method is simple and effective, easily produced, also can effectively avoid the impact of the coupling. The transducer prototype was developed by using the new method, it has only one resonance peak.

Coupling Impact Analysis

Since the thickness vibration mode frequency is relatively high, so the high-frequency transducers are generally using the thickness vibration mode of the piezoelectric vibrator. Round transducer coupling influence is mainly from the higher-order modes of radial and lateral bending mode, etc. In practice, the high frequency transducer circular transducers can't satisfy the condition that a is much greater than t , so that the transducer is often influenced by the coupling Impact.

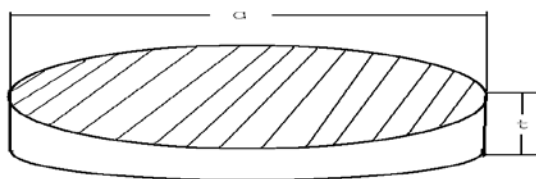


Fig. 1 Circular piezoelectric oscillator schematic

Under ideal conditions, the series resonant frequency of the thickness vibration of PZT4 is

$$f_t = \frac{1.39v_t^D}{\pi t} = \frac{2036.3}{t} \quad (1)$$

Frequency constant, vibration displacement distribution, transmission voltage response of piezoelectric transducers, directivity and other properties were affected by coupling impact. According to the operating frequency of the transducer $f_t = 218\text{kHz}$ to calculate, get $t = 9.34\text{mm}$. Keep t values unchanged, taking a diameter $a = 2t, 3t, 5t, 9t$ to analysis coupling vibration impact. The paper analysis focused on the voltage response curves and the directivity pattern of transducer changes in dependence of a value.

Figure 2 shows, when $a = 2t$, two obvious resonant peaks are present on the transmit voltage response curve, respectively, 210kHz and 248kHz , there is a deep valley between the two peaks. When $a = 3t$, the two resonant peak frequencies are 208kHz and 240kHz , the valley between the two peaks becomes shallowly.

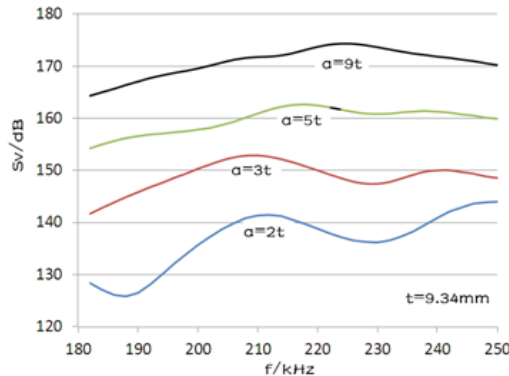


Fig. 2 Transmit voltage response curves at different a values

With the increase of the value a , the two resonant peaks frequency gradually move closer, and the valley between two peaks becomes shallowly. When $a = 9t$, the two peaks have been combined to form a resonant peak frequency of 224kHz . This phenomenon shows that when $a = 2t, 3t, 5t$, the thickness mode is coupled strongly by the radial vibration high-frequency modes and lateral bending modes. When the a is apposite value, the thickness of the vibration frequency is clear gradually.

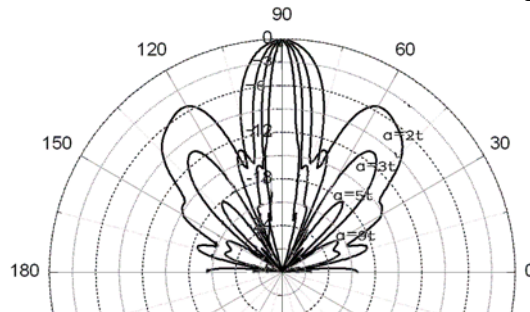


Fig. 3 218kHz directivity pattern at different value a

Figure 3 shows, at 218kHz , $a = 2t$, -6dB directivity pattern of an opening angle is 30° , the maximum side lobe level is -5dB . When $a = 3t$, the main beam angle becomes smaller, the maximum side lobe level is -10.5dB , when $a = 5t$, side lobe level is -18dB , $a = 9t$, side lobe level is -22.5dB . This phenomenon shows that when $a = 2t, 3t$, the round oscillator is affected by coupling impact. With a increasing, the transducer's directivity pattern gradually is normal, the side lobe level is reducing. Visibly, Coupling Effect in circular piston transducer are: the transmit voltage response curve have multi-resonance peaks, the directivity pattern is abnormal, the side lobe level is higher.

Oscillator center opening effect on coupling

Keep $t = 9.34\text{mm}$ and Inner diameter is 5mm , the outer diameter $a = 2t, 3t, 4t, 5t$, Analysis coupled vibration influence.

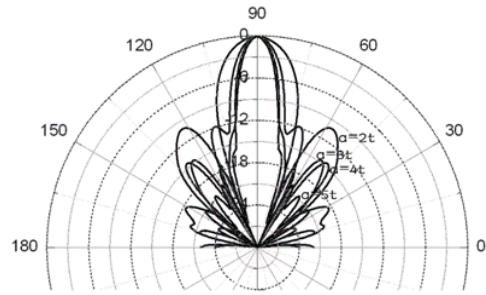
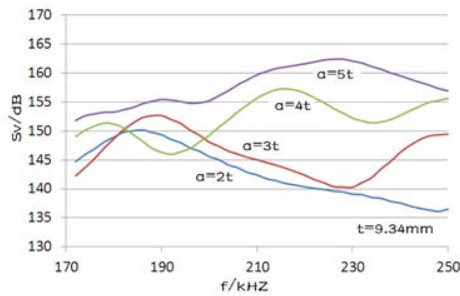


Fig. 4 center opening TVR at different a Fig. 5 center opening 218kHz directivity pattern

Figure 4 shows, $a = 2t, 3t$, the curve between 170kHz ~ 230kHz has only one resonant peak. When $a = 5t$, the curve has a main peak. Figure 5 shows, when $a = 2t$, the transducer in the 218kHz directivity pattern $-6dB$ open angle is 34° , the side lobe level is $-10.1dB$. when $a = 3t, 4t$, the maximum side lobe level is $-12dB$, $a = 5t$, the side lobe level is $-20dB$. Compare Figure 3, the primary beam open-angle has little change, but the low side-lobe level has decreased.

Contrast circular opening hole in the center and not opening two situations: the transducer with center opening easily identify the main resonance peak, and has less impact on the directivity pattern, low side-lobe level.

Experimental study of decoupling

In practice, the circular piston transducer are limited by mounting dimensions and beam open-angle. The transducer is in the range of coupling, leading to transmit voltage response curve have more resonance peaks. In order to design an operating frequency of 218kHz circular piston transducer. Uses a circular piezoelectric transducer, the piezoelectric wafer size is $\Phi 60 \times 10mm$, the circular piston transducer 's transmit voltage response data are measured in Figure 6.

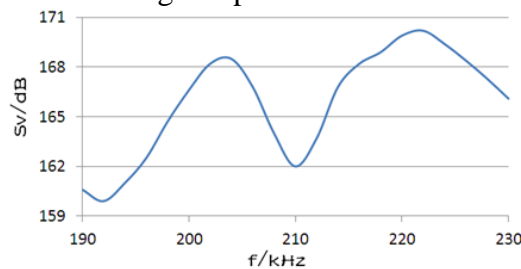


Fig. 6 218kHz transducer's TVR curve

Figure 6 shows that: there are two distinct resonant peaks, and the two peaks are close and the middle of two peaks has a deep valley, the main peak is not easy to discern. To eliminate the effects of coupling action as shown in Fig. 6, according to the principles described earlier, there are two options can be solved. The first is increasing a , i.e. the diameter increases. The second is digging a hole at the center of the circular oscillator to reduce the impact of coupling.

After much optimization, the first design of a circular transducer dimension is $\Phi 65 \times 9.8mm$, the test results shown in Figure 7~8.

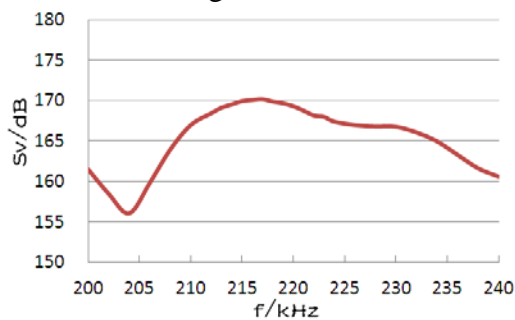


Fig. 7 $\Phi 65 \times 9.8$ transducer TVR curve

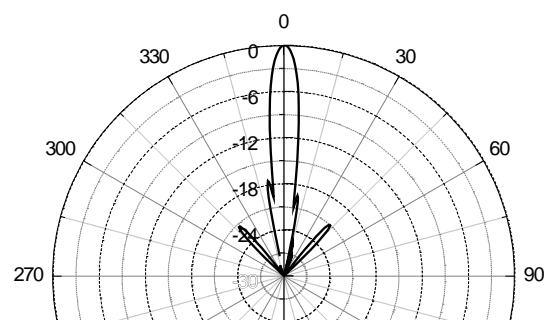


Fig. 8 $\Phi 65 \times 9.8$ 218kHz transducer directivity pattern

Figure 7-8 shows that the transducer in the vicinity of 218kHz has only one main resonance peak and transmit voltage response level is 170dB . It has less influence by the coupling effect, the beam width of 218kHz is 6.5° . The side lobe level is -21dB .

The second design of the circular transducer dimension is $\Phi 55 \times \Phi 9 \times 9.4\text{ mm}$, the transducer's test results are shown in Fig. 9 ~ 10.

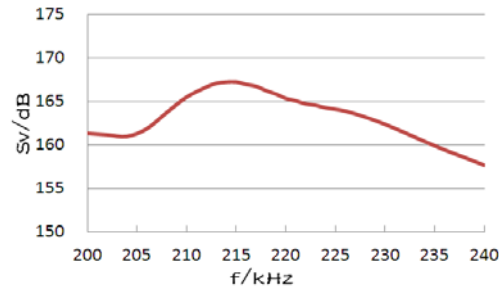


Fig. 9 $\Phi 55 \times \Phi 9 \times 9.4$ transducer TVR curve

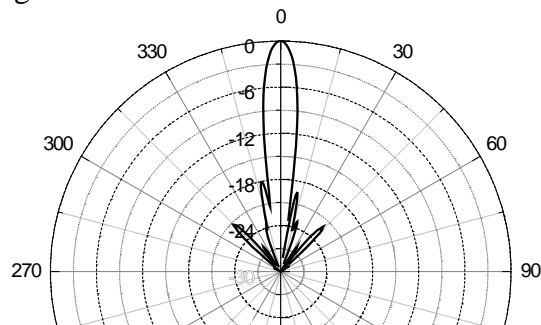


Fig. 10 $\Phi 55 \times \Phi 9 \times 9.4$ 218kHz transducer directivity pattern

Figure 9~ 10 show that, the transducer in the 218kHz has the main resonance peak significantly and less affected by the coupling effect, the resonance point of the Transmit voltage response is 167dB , the maximum source level is greater than 205dB , beam width 218kHz is 8° , lobe level is -18dB .

In conclusion

This paper analyzes the impact of coupling effect on the high-frequency circular piston transducer, focuses on diameter changes on the transmission voltage response curves and directivity pattern in the thickness of the constant. This paper also analysis the circular oscillator with a hole and without a hole to eliminate coupling effects, and experimental data are described. Two methods are valid to reduce the coupling effects, the paper propose a new method, a new method is simple to reduce coupling influence, it has a good applicability.

References

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