Simulation Analysis on Cymbal Transducer
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Abstract. The resonance frequency of the cymbal transducer ranges from 2kHz to 40kHz and its effective electromechanical coupling factor is around 20%. Finite element analysis has been performed to ascertain how the transducer’s makeup affect the transducer’s performance parameters. Two-dimensional axisymmetric model of the cymbal transducer was founded by finite element software-ANSYS, the application of the element type was discussed and the FEM models were built up under the far field condition. Eight groups of cymbal transducers of resonance frequency around 3kHz with different structural dimensions were designed. It was better for choosing the cymbal transducer of the 8mm cavity coping diameter, 20.8mm cavity bottom diameter and 26.8mm piezoelectric ceramic wafer diameter than others for reducing distortion degree of the signal and improving communication turnover in the researched cymbal transducers. It was appropriate for choosing the cymbal transducer of the 8mm cavity coping diameter, 22.4mm cavity bottom diameter and 26.4mm piezoelectric ceramic wafer diameter in order to improve the free-field voltage sensitivity and transmission efficient.

Introduction
The cymbal has a small volume, lightweight, high sensitivity, machining simple, low production cost performance, so it can be a small power transmission transducer and new sonar underwater sensor, and also can be used as actuators and acceleration sensor and so on[1,2,3]. While using for acceleration sensor, both the sensitivity and resolution are high and can be applied to ground vibration analysis, vibration stress scans and vibration table control sensitivity measuring system of faint vibration signal to improve test sensitivity of system and accuracy [4].

The performance of the cymbal transducer of the 5KHz-50KHz resonance frequency was researched in the foreign, such as sensivity, compression experiment research was did and production methods and process were introduced[5,6,7]. The electromechanical properties and vibration modal of the cymbal transducer of the 10KHz-40KHz resonance frequency were researched [8,9,10].

The cymbal transducers of eight sorts of different structure parameter of 3KHz resonance frequency were researched by ANSYS FEM in this article, finite element model is discussed, strunture parameter influence on resonance frequency is debated, and computing the bandwidth, quality factor, efficient electromechanical coefficent performance parameters, the cymbal transducer of better comprehensive performance is optimized [11].

Finite Element Analysis and Structural Parameters Design
The cymbal transducer has the axisymmetric structure, two-dimensional axisymmetric model is established to reduce storage and computing time, and analysis and calculation. The quasi-physical model of the cymbal transducer is axisymmetric, so take o as symmetry center, and take y-axis as axis of symmetry, and take xoz flat surface as symmetry in the face to build up geometric model of y-axis right half flat surface.

The model diagram of the cymbal transducer was shown in fig. 1. The relationship between the structural parameters and the resonance frequency is shown in table. 1
The ANSYS software is an major general finite element analysis software, it can carry on the analysis and calculation of the science of piezoelectricity and acoustics, it react on research and application field of science of piezoelectricity and acoustics. Considering axisymmetric performance, two-dimensional unit is selected in building up cymbal transducer. Building a modal according to the order of point, line, and surface.

**Result Analysis**

The transducer performance by calculating of ANSYS software is shown in table 2 and table 3.

**Table 1 The relationship between structural parameters and the resonance frequency**

<table>
<thead>
<tr>
<th>Sequence number</th>
<th>$t_2$ [mm]</th>
<th>$t_1$ [mm]</th>
<th>$h$ [mm]</th>
<th>$d_2$ [mm]</th>
<th>$d_1$ [mm]</th>
<th>$f_r$ [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>0.20</td>
<td>0.5</td>
<td>14</td>
<td>18.0</td>
<td>24.0</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>0.20</td>
<td>0.5</td>
<td>8</td>
<td>22.4</td>
<td>26.4</td>
</tr>
<tr>
<td>3</td>
<td>0.5</td>
<td>0.20</td>
<td>0.5</td>
<td>9</td>
<td>21.6</td>
<td>27.6</td>
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<tr>
<td>4</td>
<td>0.5</td>
<td>0.20</td>
<td>0.5</td>
<td>10</td>
<td>22.0</td>
<td>30.0</td>
</tr>
<tr>
<td>5</td>
<td>0.5</td>
<td>0.20</td>
<td>0.5</td>
<td>12</td>
<td>18.0</td>
<td>24.0</td>
</tr>
<tr>
<td>6</td>
<td>0.5</td>
<td>0.20</td>
<td>0.5</td>
<td>10</td>
<td>20.0</td>
<td>24.0</td>
</tr>
<tr>
<td>7</td>
<td>0.5</td>
<td>0.20</td>
<td>0.5</td>
<td>8</td>
<td>20.8</td>
<td>26.8</td>
</tr>
<tr>
<td>8</td>
<td>0.5</td>
<td>0.20</td>
<td>0.5</td>
<td>7</td>
<td>21.0</td>
<td>27.0</td>
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</tbody>
</table>

**Table 2 The simulation performance test of the cymbal transducer**

<table>
<thead>
<tr>
<th>Sequence number</th>
<th>$f_B$ [kHz]</th>
<th>$G_{max}$ [mS]</th>
<th>$B_2$ [mS]</th>
<th>$f(B_{max})$ [kHz]</th>
<th>$f(B_{min})$ [kHz]</th>
<th>$FFVS_{max}$ [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.85</td>
<td>0.0187</td>
<td>0.109</td>
<td>2.75</td>
<td>2.95</td>
<td>-167.362</td>
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<tr>
<td>2</td>
<td>2.90</td>
<td>0.0704</td>
<td>0.128</td>
<td>2.75</td>
<td>3.05</td>
<td>-161.226</td>
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<tr>
<td>3</td>
<td>3.20</td>
<td>0.0703</td>
<td>0.152</td>
<td>3.05</td>
<td>3.35</td>
<td>-163.679</td>
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<td>3.00</td>
<td>0.0672</td>
<td>0.174</td>
<td>2.85</td>
<td>3.15</td>
<td>-164.589</td>
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<td>5</td>
<td>3.50</td>
<td>0.0309</td>
<td>0.135</td>
<td>3.40</td>
<td>3.65</td>
<td>-167.973</td>
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<tr>
<td>6</td>
<td>3.60</td>
<td>0.0599</td>
<td>0.131</td>
<td>3.40</td>
<td>3.75</td>
<td>-164.418</td>
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<tr>
<td>7</td>
<td>3.50</td>
<td>0.0714</td>
<td>0.161</td>
<td>3.30</td>
<td>3.70</td>
<td>-164.509</td>
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<td>8</td>
<td>2.40</td>
<td>0.0690</td>
<td>0.151</td>
<td>3.20</td>
<td>3.55</td>
<td>-164.006</td>
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</tbody>
</table>

**Table 3 The simulation performance test of the cymbal transducer**

<table>
<thead>
<tr>
<th>Sequence number</th>
<th>$f_B$ [kHz]</th>
<th>$Q_w$</th>
<th>$Q_T$</th>
<th>$k_{eff}$</th>
<th>$R_{eq}$ [kΩ]</th>
<th>$C_{eq}$ [nF]</th>
<th>$L_{eq}$ [H]</th>
</tr>
</thead>
<tbody>
<tr>
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<td>200</td>
<td>14.25</td>
<td>5.84</td>
<td>0.1090</td>
<td>53.53</td>
<td>0.073</td>
<td>42.62</td>
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<tr>
<td>2</td>
<td>300</td>
<td>9.67</td>
<td>1.82</td>
<td>0.2319</td>
<td>14.21</td>
<td>0.400</td>
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</tr>
<tr>
<td>3</td>
<td>300</td>
<td>10.67</td>
<td>2.16</td>
<td>0.2039</td>
<td>14.23</td>
<td>0.328</td>
<td>7.55</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>10.00</td>
<td>2.60</td>
<td>0.1925</td>
<td>14.88</td>
<td>0.357</td>
<td>7.90</td>
</tr>
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<td>5</td>
<td>250</td>
<td>14.00</td>
<td>4.37</td>
<td>0.1268</td>
<td>32.39</td>
<td>0.100</td>
<td>20.63</td>
</tr>
<tr>
<td>6</td>
<td>350</td>
<td>10.29</td>
<td>2.20</td>
<td>0.2057</td>
<td>16.69</td>
<td>0.258</td>
<td>7.59</td>
</tr>
<tr>
<td>7</td>
<td>400</td>
<td>8.75</td>
<td>2.25</td>
<td>0.2199</td>
<td>14.01</td>
<td>0.371</td>
<td>5.58</td>
</tr>
<tr>
<td>8</td>
<td>350</td>
<td>9.71</td>
<td>2.18</td>
<td>0.2103</td>
<td>14.49</td>
<td>0.333</td>
<td>6.59</td>
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</table>
Taking the NO.2 transducer for example, the admittance modulus curve, conductance-susceptance curve and admittance circle curve were shown in fig. 2, fig. 3 and fig. 4.

![Fig. 2. The admittance modulus curve](image1)

![Fig. 3. The conductance-susceptance curve](image2)

![Fig. 4. The admittance circle curve](image3)

The free-field voltage sensitivity of the NO.1 to NO.8 transducers are shown in fig. 5(a), (c).

![Fig. 5. The free-field voltage sensitivity curve](image4)

According to table 1 and table 2, the -3dB bandwidth of the cymbal transducer of the 8mm cavity coping diameter, 20.8mm cavity bottom diameter and 26.8mm piezoelectric ceramic wafer diameter was the broadest and up to 400Hz, the mechanical quality factor $Q_m$ and the electrical quality factor $Q_e$ of the cymbal transducers of the 8mm cavity coping diameter, 22.4mm cavity bottom diameter and 26.4mm piezoelectric ceramic wafer diameter, the 9mm cavity coping diameter, 21.6mm cavity bottom diameter and 27.6mm piezoelectric ceramic wafer diameter and the 8mm cavity coping diameter, 20.8mm cavity bottom diameter and 26.8mm piezoelectric ceramic wafer diameter were smaller, thereinto, the mechanical quality factor $Q_m$ of the cymbal transducer of the 8mm cavity coping diameter, 20.8mm cavity bottom diameter and 26.8mm piezoelectric ceramic wafer diameter was the smallest and up to 8.75, while the electrical quality factor $Q_e$ of the cymbal transducer of the 9mm cavity coping diameter, 21.6mm cavity bottom diameter and 27.6mm piezoelectric ceramic wafer diameter was the smallest and up to 2.16. The efficient electromechanical coupling coefficient and the free-field voltage sensitivity of the cymbal transducer of the 8mm cavity coping diameter, 22.4mm cavity bottom diameter and 26.4mm piezoelectric ceramic wafer diameter were the largest,
and respectively up to 0.2319 and -161.226dB. In conclusion, the comprehensive performance of the cymbal transducer of the 8mm cavity coping diameter, 22.4mm cavity bottom diameter and 26.4mm piezoelectric ceramic wafer diameter was the best among them.

Conclusion
The performance parameters of the transducers were closely related to itself structural parameters and material parameters, it was significant superiority to design transducer by FEM. It was better for choosing the cymbal transducer of the 8mm cavity coping diameter, 20.8mm cavity bottom diameter and 26.8mm piezoelectric ceramic wafer diameter than others for reducing distortion degree of the signal and improving communication turnover in the researched cymbal transducers. It was appropriate for choosing the cymbal transducer of the 8mm cavity coping diameter, 22.4mm cavity bottom diameter and 26.4mm piezoelectric ceramic wafer diameter in order to improve the free-field voltage sensitivity and transmission efficient. Taking one with another, we can design cymbal transducer with different performance parameters according to different parameters demand.

Acknowledgements
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References