Study on the Characteristics of Acoustic Radiation of Microspeaker Associated with Pattern of Diaphragm with Finite Element Method

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Abstract. The objective of this study is to investigate the acoustic radiation of Microspeaker based on various pattern geometries of diaphragm. The influence of first resonant frequency ($f_0$) is discussed, as are the radiation efficiency (SPL) and impedance curve (IMP). First, microspeaker geometry was reconstructed with CAD software (Creo). Four geometric pattern parameters, width, angle, depth, and quantity, of microspeaker diaphragm were defined and simulated with commercial finite element software - COMSOL Multiphysics. Results showed that the quantity and depth of pattern significantly influenced on the acoustic radiation, especially at lower frequencies. The stiffness of diaphragm decreased with increases in quantity and depth of pattern. In addition, $f_0$ for both conditions shifted to lower frequency and bandwidth of microspeaker was extended. Increasing the angle of pattern, resulted in more solid diaphragm and slight increase in efficiency.

Introduction

The diaphragm is an important factor in acoustic radiation and microspeaker bandwidth improvement. To date, there are plenty of ways to simulate and predict the performance of microspeaker. One of the most powerful is the finite element method (FEM) with commercial software. In 2004, Larsen [1] proposed that the material properties and geometries of diaphragm plays important roles in simulation. Few studies related to the pattern of diaphragm are available in the literature. M. R. Bai et al. [2] demonstrated optimization of the pattern of diaphragm with the combination of FEM and ECM (equivalent circuit method). In 2010, Alex Salvatti [3] obtained good performance with measurement based on precision material properties and geometries.

To understand the influence of pattern on microspeaker diaphragm, this study began with reconstruction of the microspeaker geometry. Four conditions for diaphragm pattern were defined and investigated. The variations in radiation efficiency (SPL), impedance curve (IMP), and first resonant frequency ($f_0$) were simultaneously simulated with FEM software-COMSOL Multiphysics.

Descriptions of Microspeaker

Based on real microspeaker of 23.8 mm diameter, a new geometry for simulation was reconstructed with CAD software-Creo, as shown in Figure 1. Four conditions of diaphragm pattern, width, angle, depth, and quantity shown in Figure 2, were defined and used the simulation. To check for accuracy, in the beginning, this model was simulated with COMSOL Multiphysics and compared with measured results of SPL as shows in Figure 3. There was good agreement between simulation and measurement, especially at frequencies below 4 kHz. Due to the influence of material properties of diaphragm, there were some differences in the level of SPL only at higher frequencies. In general, the simulated performance of microspeaker at higher frequencies closely with the measurement. Therefore, investigations of pattern of diaphragm can be carried out with simulation. Four geometric parameters of pattern of diaphragm for microspeaker adopted in the simulation are summarized in Table 1.
Figure 1. Microspeaker; (a) real case; (b) simulation case.

Figure 2. Schematic diagram of four geometric parameters for pattern of the microspeaker diaphragm; (a) width; (b) angle; (c) depth; (d) quantity.

Figure 3. Comparisons of SPL between measurement and simulation.

Table 1. Geometric parameters of pattern for the original simulation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Width [mm]</th>
<th>Included angle [deg.]</th>
<th>Radius of reference path [mm]</th>
<th>Depth [mm]</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.45</td>
<td>50</td>
<td>30</td>
<td>0.35</td>
<td>30</td>
</tr>
</tbody>
</table>

Parametric Analysis

The parametric analysis of these four parameters of pattern were investigated with COMSOL Multiphysics. Discussions will focus on the influence of SPL and IMP, as well as $f_0$ and efficiency.

(a). Width

The width of pattern was simulated based on 3 conditions, {0.3 mm, 0.45 mm, 0.675 mm}. Both SPL and IMP are shown in Figure 4. Results showed that the width of pattern does not influence SPL or IMP, even when $f_0$ is fixes at 250 Hz, as shown in Table 2.
Figure 4. The influence of width; (a) SPL; (b) IMP.

Table 2. The value of $f_0$ in three situation.

<table>
<thead>
<tr>
<th>Size [mm]</th>
<th>0.3</th>
<th>0.45</th>
<th>0.675</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_0$ [Hz]</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
</tbody>
</table>

(b). Angle

Three angles of pattern, $\{30^\circ, 50^\circ, 70^\circ\}$, shown in Table 3, were investigated. Figure 5 shows the simulation results. Obviously, the larger the angle, the higher the $f_0$. In other words, the stiffness of diaphragm increases with the angle of pattern. In addition, the efficiency of radiation at higher frequencies slight rises rose slightly. More depth led to increases in mechanical resistance and significant drops in the level of IMP at $f_0$.

Figure 5. The influences of angle; (a) SPL; (b) IMP.

Table 3. The value of $f_0$ in three situations.

<table>
<thead>
<tr>
<th>Size [mm]</th>
<th>30</th>
<th>50</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_0$ [Hz]</td>
<td>250</td>
<td>250</td>
<td>315</td>
</tr>
</tbody>
</table>

(c). Depth

We also investigated the influence of depth of pattern. Three conditions, 0.225 mm, 0.35 mm, and 0.44 mm, were simulated, as shown in Figure 7 and Table 5. The deeper the pattern, the softer the diaphragm. Therefore, $f_0$ shifted to lower frequency. More interesting is that there was almost no change in $f_0$ when the depth increased to 0.35 mm. This means that variations in depth of pattern are limited.
Quantity

Quantities are commonly used to reduce the stiffness of diaphragm and $f_0$ to achieve extensions of microspeaker bandwidth. The quantities of 0, 15, and 30, were used for simulation. Simulation results for SPL and IMP are shown in Figure 8. It was demonstrated that $f_0$ shifts to lower frequencies with increase in quantity of pattern from 400 Hz to 250 Hz. In other words, the stiffness of diaphragm is reduced with increase in quantity of pattern. In addition, higher efficiency is achieved at higher frequencies.

Summary

The influence of the geometry of pattern were comprehensively investigated with finite element simulation. The quantity and depth of pattern significantly influenced the stiffness of diaphragm and induced $f_0$ to move to lower frequency. In addition, both slightly increased the efficiency of microspeaker at frequencies above 7 kHz. Conversely, angle of pattern led to increases in stiffness and $f_0$. Additionally, mechanical resistance increased with the angle of pattern. Based on these results,
the parametric analysis and simulation of diaphragm pattern of microspeaker presented in this study are not only useful for predicting the influence of pattern, but also for the preliminary design of microspeaker.

References

