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Vibration and Acoustic Analysis for the Speaker Cover of the Automotive Trim

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Abstract. In general, a mesh cover is attached to the front of the speaker to protect the speaker. Experiments have confirmed that the sound pressure changes depending on the distance between the speaker and the cover, the thickness of the cover, and the like. The result of calculating this phenomenon using the FE model is introduced. It was confirmed that due to the influence of the cover, the sound pressure increased due to the resonance phenomenon below a specific frequency, and the sound pressure decreased due to the sound insulation effect above that frequency range. Similar results were obtained when the cover thickness was changed. We also report the calculation results even though the hole diameter is changed and when the distance between the cover and air is changed.

1. Introduction

In general, speakers are installed on the doors of automobiles, and the door trim has a porous cover (Fig. 1) on the front of the speakers to protect the speakers. It has been confirmed from experiments and calculations that the sound pressure level generated by the speaker changes depending on the distance between the speaker and the cover, the thickness of the cover, etc. [1][2]. Previous studies have confirmed that the sound in the high frequency range is reduced, and the effect of a low-pass filter can be expected. We introduce the results of vibro-acoustic calculations using a finite element model for the effects of hole diameter, distance to the speaker, and cover thickness.

(a) Door trim for automobile

(b) Speaker cover (reverse side)

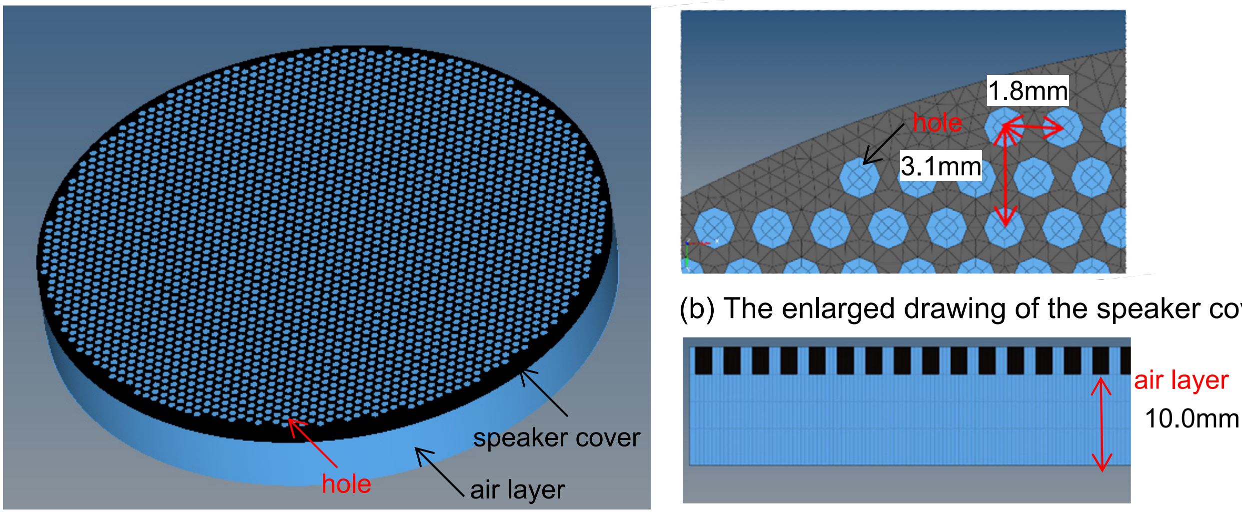
Fig. 1. Speaker cover of the door trim for automobile.

2. Comparison of Experimental Results and Calculation Results

First, in order to confirm the analysis accuracy of the finite element model, we compared the experimental measurement results with the calculation results. Fig. 2 shows the speaker cover and experimental equipment used in this measurement. A speaker cover was created by drilling approximately 2600 holes of the same size with a diameter of 1.3 mm in a 100 mm diameter range on an acrylic plate with a thickness of 3 mm and a diameter of 120 mm (left figure). The cover was placed 10 mm away from the tip of the hose speaker, and a Mic was placed 1000 mm away from the cover to measure the sound pressure level when the speaker sound pressure was applied. Fig. 3 shows the FE model. A 10 mm thick air layer and a rigid plate on the bottom surface were installed on a cover with a diameter of 100 mm and a thickness of 3mm and 100 Hz~8000 Hz vibration is applied to the top and bottom. The sound pressure level was obtained in the same way as in the experiment. Fig. 4 shows the comparison results between the experiment and calculation. The sound pressure level with the cover on the left and the sound without the cover on the left show good agreement up to 7000 Hz, but the frequency range above it does not match. High frequency above 7000 Hz is a future subject.

(a) Speaker cover (b) Speaker cover and microphone

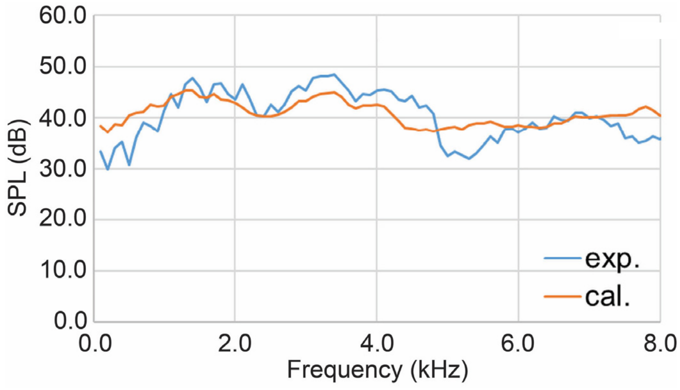
Fig. 2. Experimental setup.



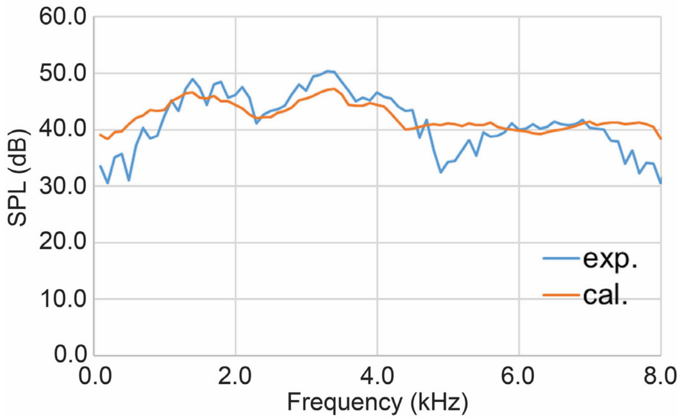
(b) The enlarged drawing of the speaker cover

(a) The survey of the speaker cover (c) The section of the speaker cover

Fig. 3. FE model of speaker cover.



(a) with cover



(b) non cover

Fig. 4. Comparison of experimental results and calculation results.

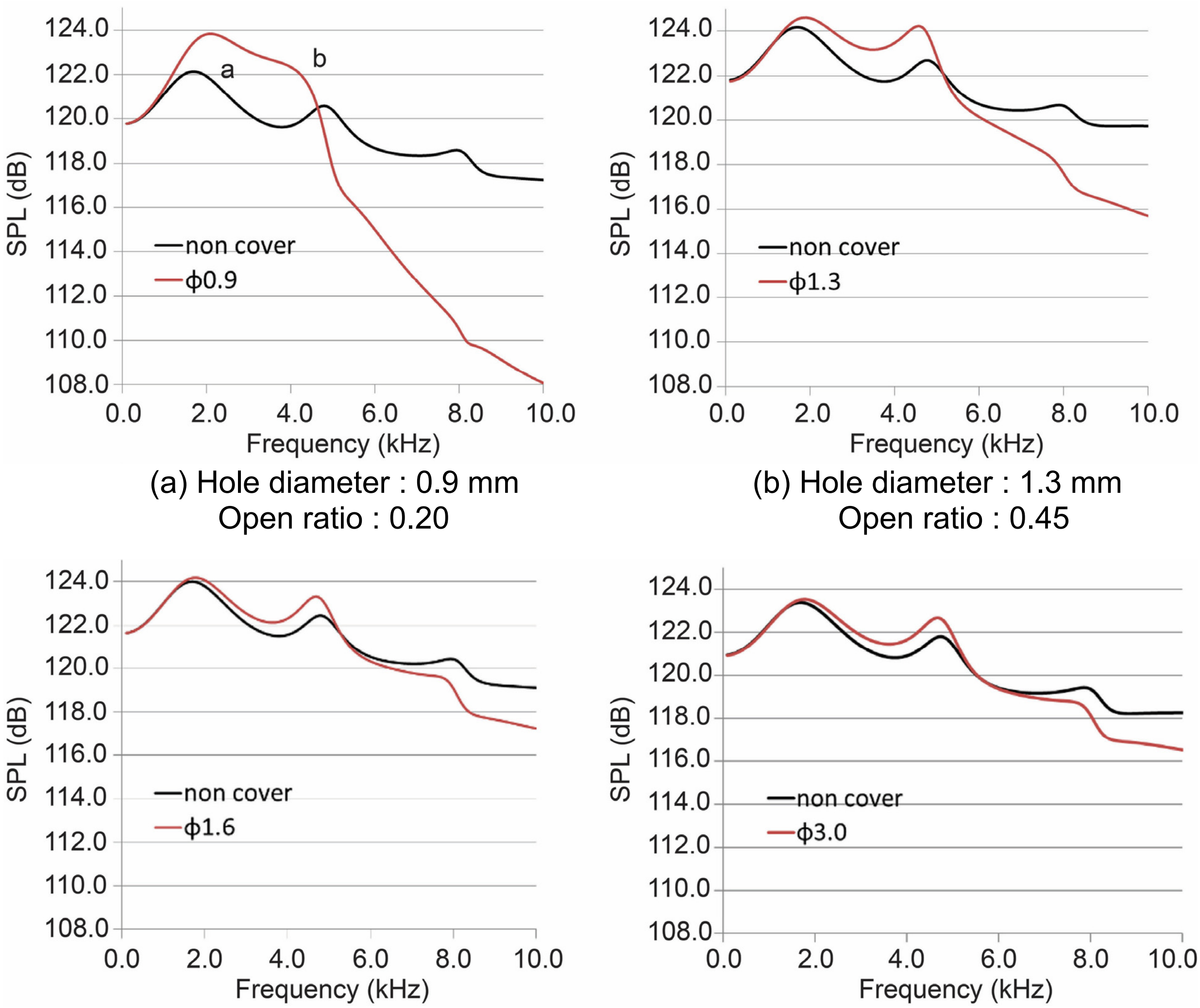
3. Calculation Results

Fig. 5 shows the results of a comparison of sound pressure levels with and without a cover. The red line in the figure is with cover, and the black line is without cover. The hole diameter and open ratio are 0.9 mm and 0.2, 1.3mm and 0.45, 1.6 mm and 0.66, 3.0 mm and 0.66 respectively. The number of holes is about 2600 for a ~ c and about 750 for d. In all the calculation results up to 5000 Hz, the sound pressure level with cover is higher than that without cover. In the higher frequency range, the sound pressure level shows a small value because the cover functions as sound insulation. In addition, comparing c and d, it can be seen that the difference in sound pressure with and without the cover increases as the hole diameter decreases even at the same open ratio. The sound pressure peak is the radial acoustic mode, and the sound pressure distribution is shown in Fig. 6. 1900 Hz was the radial first acoustic mode (left figure), and 4500 Hz was the radial second acoustic mode (right figure).

Next, Fig. 7 shows the result of comparing the cover thickness from 3 mm to 1 mm and 5 mm. Up to a certain frequency, the thicker cover shows a larger value. But when the frequency is higher, it can be seen that the thicker one shows a smaller value due to the sound insulation effect of the cover the same as Fig. 6.

Next, Fig. 8 shows the results of comparison with the air layer thickness changed from 10 mm to 5 mm, 13 mm, 15 mm, and 20 mm. Up to around 2000 Hz, the larger the air layer thickness, the larger the peak value. But the sound pressure decreases at the higher frequency range. However, it can be seen that when the air layer is thickened, resonance in the vertical direction occurs and the sound pressure increases. The part circled in the figure is the peak in the vertical direction at an air layer of

20 mm. Therefore, it was found that the air layer has a wide frequency range where the sound pressure is reduced to about 13 mm. In the future, we would like to make use of the knowledge obtained from these calculation results when considering the reduction of high-frequency sound using a perforated plate.



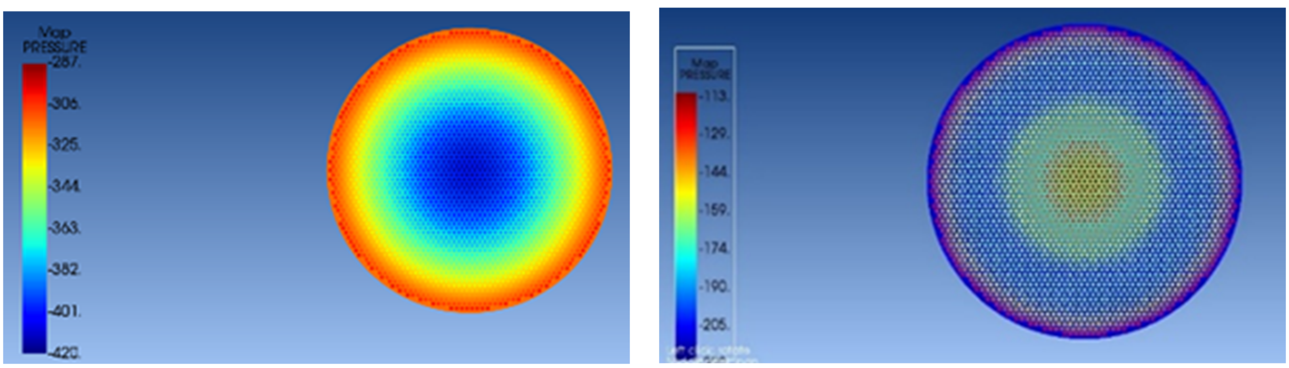
(a) Hole diameter : 0.9 mm
Open ratio : 0.20

(b) Hole diameter : 1.3 mm
Open ratio : 0.45

(c) Hole diameter : 1.6 mm
Open ratio : 0.66

(d) Hole diameter : 3.0 mm
Open ratio : 0.66

Fig. 5. SPL for with / without cover.



(a) 1900.0 Hz

(b) 4500.0 Hz

Fig. 6. Acoustic mode.

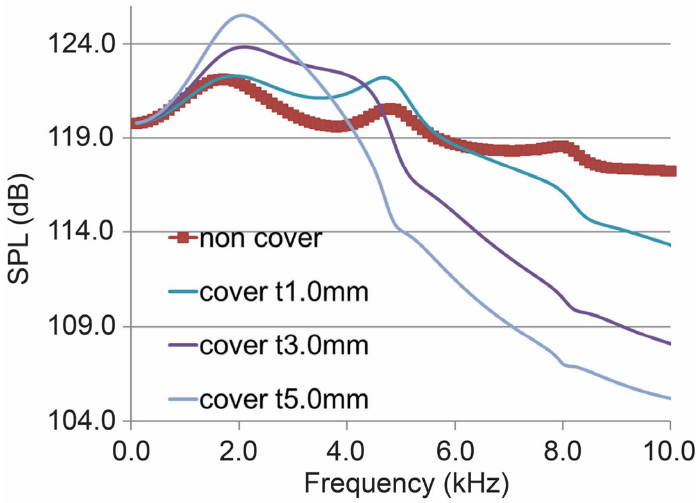


Fig. 7. Calculation result of SPL by difference in cover thickness.

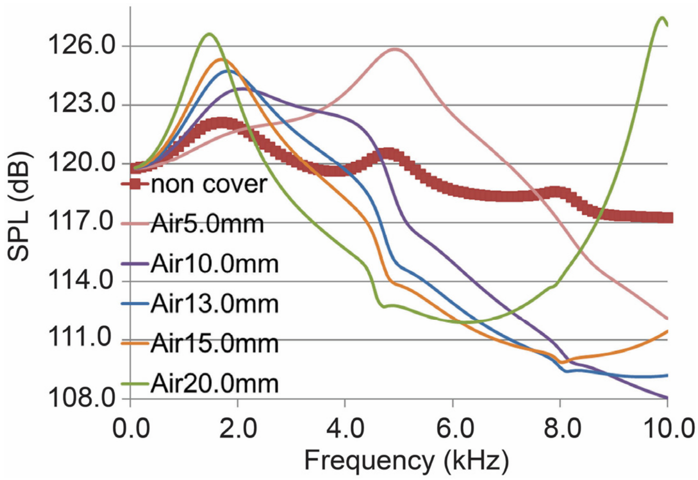


Fig. 8. Calculation result of SPL by difference in air layer thickness.

4. Conclusion

As a result of the vibro-acoustic analysis of a porous speaker cover by an FE model, the following was found.

- The sound pressure increases due to the resonance phenomenon of the air layer below a certain frequency (5000 Hz for ϕ 1.3 mm), and the sound pressure decreases due to the sound insulation effect above that frequency range.
- In the calculation for hole diameter 1.6 mm, 1.3 mm, 0.9 mm, the sound pressure was reduced most in ϕ 0.9 mm with a small open ratio. Furthermore, the smaller the open ratio and the diameter, the more the sound pressure can be reduced.
- In the calculation for cover thickness 1 mm, 3 mm and 5 mm, 5 mm thickness had the lowest sound pressure. The bigger thickness, the more the sound pressure can be reduced.
- With 13 mm air layer between the speaker and the cover, the sound pressure was reduced in the widest frequency range.

From these calculation results, we would like to consider a porous plate as a low-pass filter in the high frequency range.

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