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Effect of Wall Sound Absorption by Car Door Speakers and Sound Pressure Distribution in the Car

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Abstract. In order to analyze how the sound emitted from the speaker of an automobile changes due to the influence of the wall, we performed an experiment and a calculation using the FE model for the case of a rectangular parallelepiped box with and without a sound absorbing material on the wall. The calculation results were able to roughly reproduce the experimental results. Next, we created a simple FE model that simulates the interior space of a car, and used the actual vehicle to determine the effects of sound absorption on the ceiling, floor, and seats, and changes in sound pressure level and sound pressure distribution when sound absorbing materials were added. We report the measurement and analysis results by the FE model.

1. Introduction

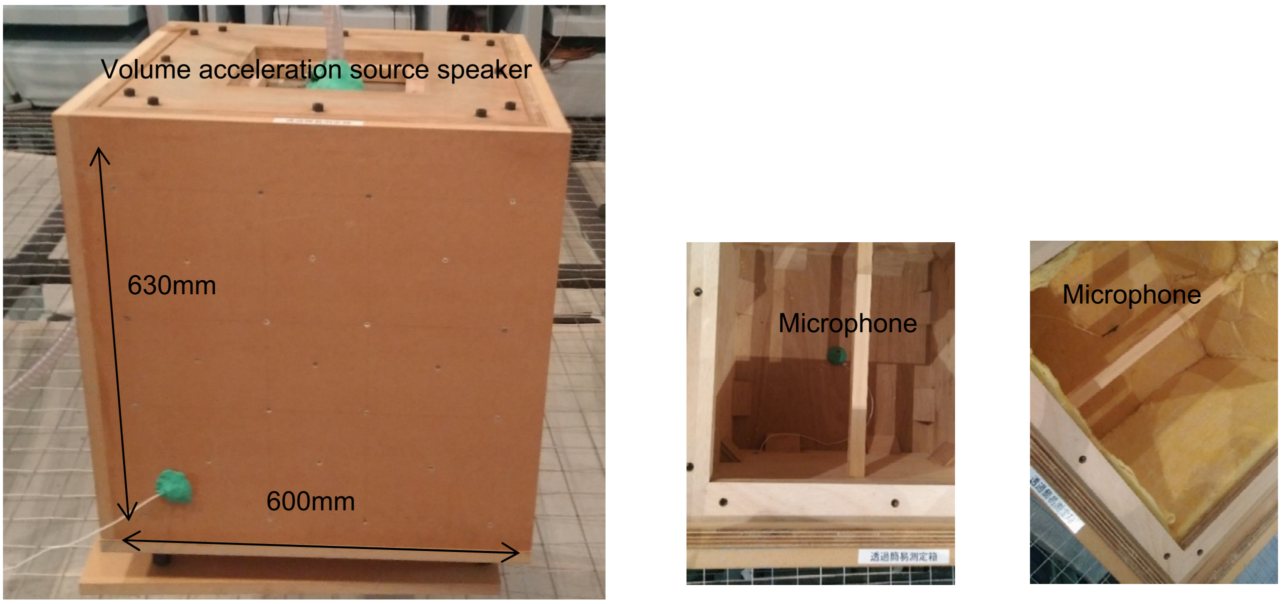
Generally, speakers are installed on the doors of automobiles to transmit music and information during driving. The sound emitted from the speaker is reflected on the walls (trims, etc.) inside the vehicle and reaches the ears of the occupants. Therefore, it is considered that the sound pressure from the speaker to the interior of the automobile is greatly affected by the sound absorption by the wall, especially in the high frequency range. In this research, first, how the sound pressure emitted from the speaker changes due to the influence of the wall, the sound absorbing material of the wall (glass wool (hereinafter GW) thickness 50 mm) in a rectangular parallelepiped (inner dimension 600 mm × 600 mm × 630 mm) box For the presence or absence of), experiments and calculations using the FE model were performed. Next, we created an FE model that simulated the interior space of an automobile, and examined the effects of sound absorption on walls (ceilings and floors of automobiles) and changes in sound pressure and sound pressure distribution when sound absorbing materials were added (Lexus UX). And the analysis by the FE model was performed. We will introduce these results.

2. Experiments and calculation results using test pieces

First, in order to confirm the analysis accuracy of the finite element model, we compared the experimental measurement results and the calculation results with a test piece (rectangular parallelepiped). Fig. 1 shows the test piece used in this measurement and the state of the experiment. The test piece is a rectangular parallelepiped box with an internal dimension of 600 mm x 600 mm and a height of 630 mm. The wall is made of wood with a thickness of 48 mm. A hose speaker for volume acceleration sound source was installed in the center of the upper surface, and a microphone was installed in the center of the bottom surface at a position 80 mm from the bottom surface to measure

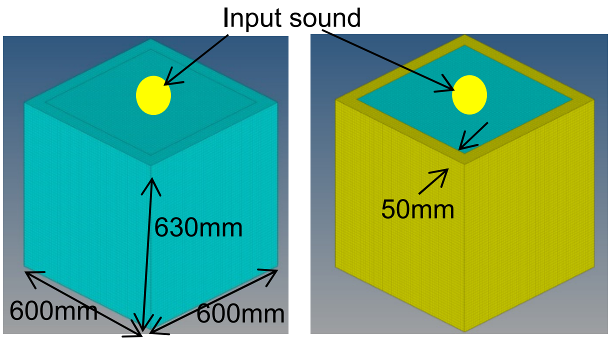
the sound pressure level. Fig. c shows a state in which GW 32 kg / m^2 with a thickness of 50 mm is installed on five surfaces excluding the upper surface. GW covers 89% of the wall surface, and the volume is 36% of the internal space (air). Fig. 2 shows a finite element model of a simple model. The Fig. 2 on the left is an air-only model. The light blue part is air, which has about 230,000 elements at a pitch of 10 mm. Since the wall of the test piece used this time is sufficiently thick, it is not modeled because the influence of wall vibration is small. It is a model that totally reflects on the wall.
The yellow circle in the Fig. 2 indicates the position of the sound source. Fig. b is a model with GW installed. The yellow part is GW. GW reverse-identified the Biot parameters (flow resistivity, porosity, tortuosity, viscous characteristic length, thermal characteristic length) so that the sound absorption coefficient measured in advance with impedance tube could be reproduced, and modeled with Rigid frame model [1]. Fig. 3 shows the measurement results of the vertical incident sound absorption coefficient of GW and the calculation results by the transmission matrix method [1] using the identified parameters. It was confirmed that the values were close to each other.

Fig. 4 shows a comparison between the measurement results and the calculation results of the sound pressure level of the test piece. As for the calculation result, the sound pressure of 100 Hz to 10000 Hz was calculated using the volume velocity as a sound source, and the volume acceleration measurement result of the sensor at the tip of the hose speaker was converted into the volume velocity and multiplied by the sound pressure and displayed in decibels. Fig. a shows the results without GW and Fig. b shows the results with GW. In both cases, the calculation results were able to roughly reproduce the experimental results. Fig. 5 shows a comparison of sound pressure levels with and without GW based on the calculation results of the FE model. Averaged for each octave band frequency for clarity. There was almost no difference in the 125 Hz band with and without GW, and a difference appeared from the 250Hz band, and there was a difference in sound pressure level of about 20dB above the 500 Hz band. This is consistent with the tendency of the frequency characteristics of the sound absorption coefficient of GW (low frequency: small, high frequency: large).



(a) Box of rectangular parallelepiped (b) Inside the box (c) Installed glass wool

Fig.1. Test piece (box) and experimental setup.



a. Air only b. Air and glass wall

Fig. 2. FE model of the test piece.

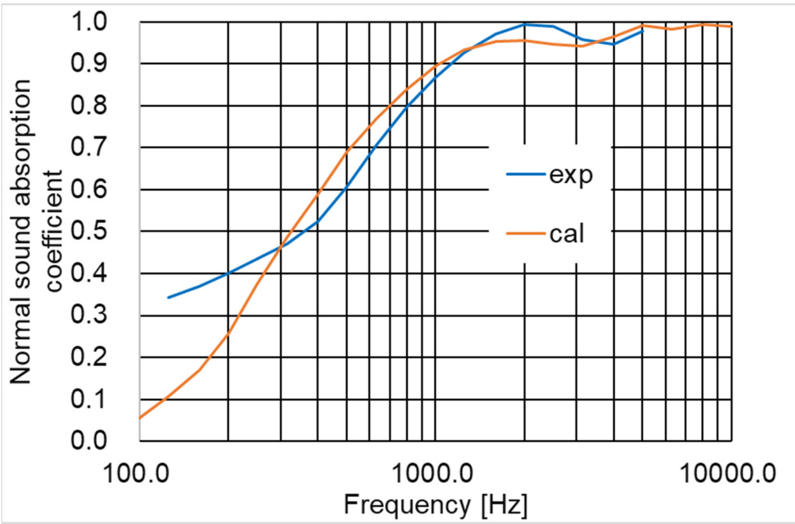
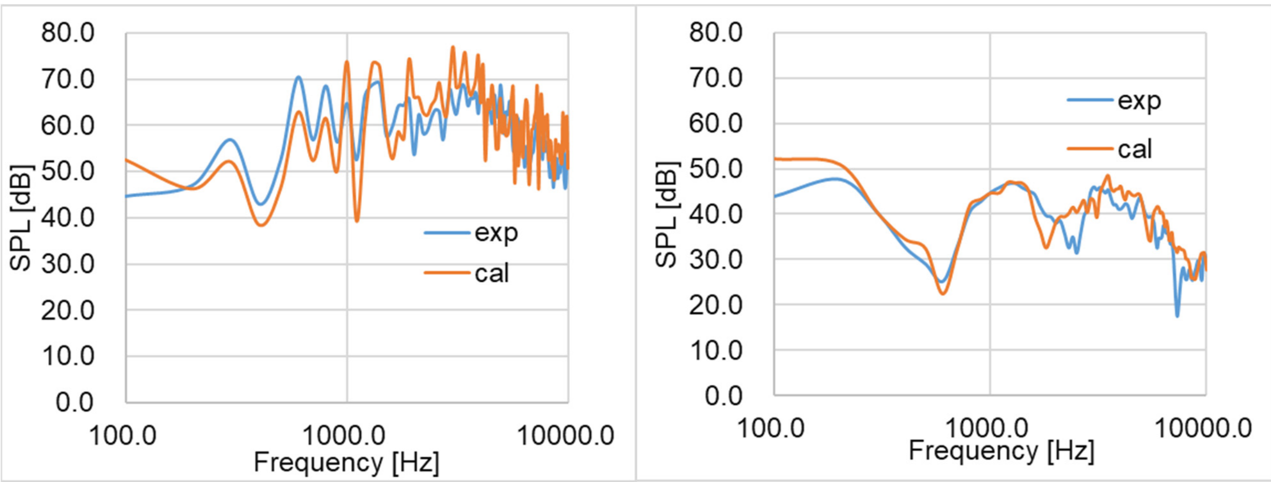


Fig. 3. Normal sound absorption coefficient of GW.



(a) Non glass wool (b) With glass wool

Fig. 4. Comparison of experimental results and calculation results for sound pressure level by test piece.

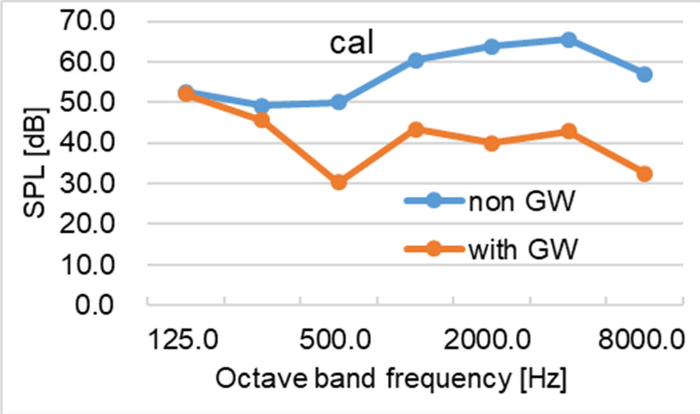


Fig. 5. Comparison of non/with glass wool for sound pressure level by test piece.

3. Experimental results and calculation results using actual vehicles

3.1 Actual vehicle experiment and FE model

Fig. 6 shows the vehicle (Lexus UX) used in this experiment. It is a leather seat vehicle. Fig. 7 shows the arrangement of measuring instruments. In order to measure the influence of the wall when the sound emitted from the speaker reaches the occupant's ear, we thought that the reciprocity theorem holds this time, and installed a hose speaker in the center of the occupant's ear position, and the center position of the in-vehicle speaker on the left, right, front and rear door trim Four microphones were installed in. This time, in order to eliminate the effect [2] on the sound of the mesh-shaped speaker cover, a curing tape was attached to the speaker cover, and a microphone was installed floating on urethane. Fig. 8 shows the PET material (polyester fiber material: white part in the Fig. 8) additionally installed. It has the same shape as the option mat and is 50 mm thick.

Fig. 9 shows the FE model used in this calculation. The space inside the vehicle is modeled with tetra mesh air, and the mesh pitch is about 10 mm and about 3.11 million elements. This model is a simple shape model created by measuring the dimensions of the interior of the actual vehicle, and the detailed wall shape cannot be reproduced. The sound source was set at the same position as in the experiment, and the sound pressure of 100 Hz to 10000 Hz was calculated at the center position of the four speaker covers. The sound absorption coefficient of the roof and floor (red part in the Fig. 9) and the seat and backrest (center part of the seat) were measured by the EA method and set as boundary conditions. The roof area is 1.366m^2, which is about 6.4% of the surface area of the model wall, and the floor area is 1.89m^2, which is about 8.8%.The other walls were completely reflected. Fig. 10 shows the measurement results of the sound absorption coefficient of the roof, floor, seat, and backrest. The FE model (red part) of the PET material added in Fig. 11 is shown. The area is 0.964m^2, which is about 4.5% of the surface area of the wall part of the model, and the volume is 0.0482m^3, which is 1.8% of the space part of the model. The measurement results of the sound absorption coefficient of the PET material added in Fig. 12 and the calculation results by the transmission matrix method using the identified Biot parameters are shown. Since the PET material was thick, it was cut out to a thickness of 15 mm, the vertical incident sound absorption coefficient was measured with impedance tube, the Biot parameter was identified, and the sound absorption coefficient to a thickness of 50 mm was calculated.

Fig. 6. The vehicle which was used by this experiment.

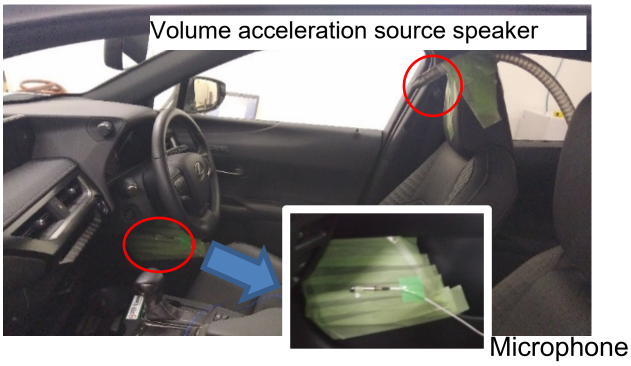


Fig. 7. Experimental setup of volume acceleration source speaker and microphone.

Fig. 8. Added sound absorption material (PET : thickness 50mm).

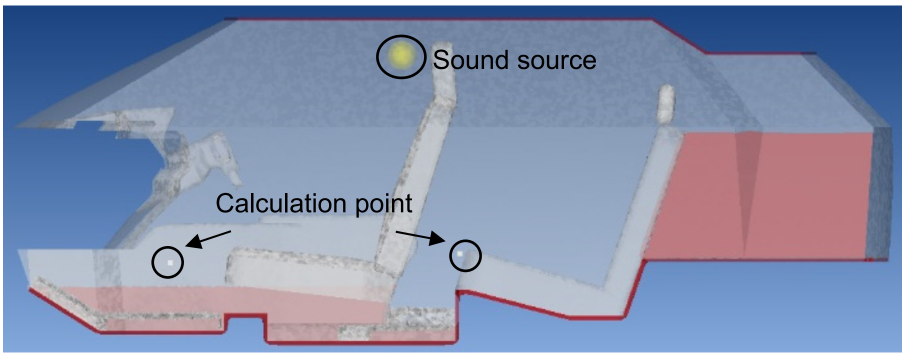


Fig. 9. Simple shape FE model.

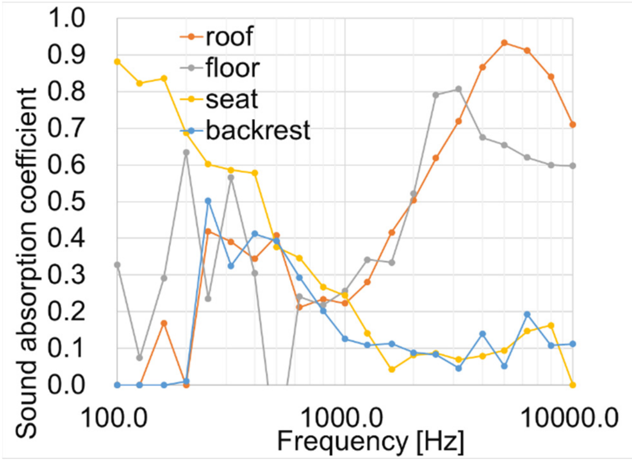


Fig.10. Sound absorption coefficient of floor and roof and sheet and backrest.

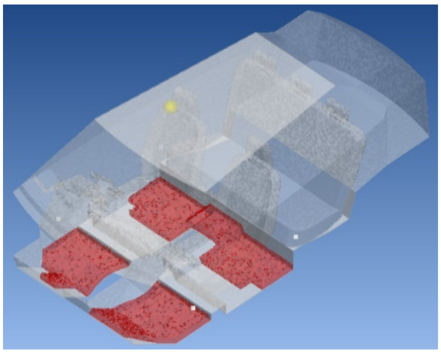


Fig. 11. Added sound absorption material for FE model (Red parts).

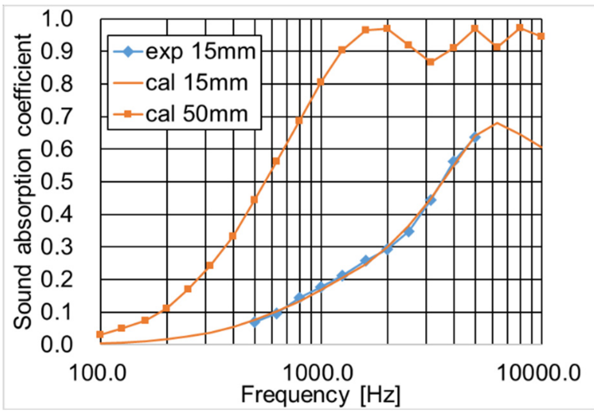


Fig. 12. Sound absorption coefficient of added sound absorption material.

3.2 Measurement results and calculation results

Fig. 13 shows a comparison between the measurement results and the calculation results of the sound pressure level. From the top, the front right door (FR), front left door (FL), rear right door (RR), and rear left door (FL). The trends are almost the same, but the analysis accuracy was insufficient at frequencies below 1000 Hz. It is considered that the detailed shape of the wall in the passenger compartment, the space behind the trim, the vibration of the wall surface, etc. are not modeled. I would like to make it a future issue. Fig. 14 shows a comparison of the experimental results with and without PET. In the test piece (Fig. 5), the tendency of the frequency characteristic of the sound absorption coefficient of the sound absorbing material and the tendency of the difference in the sound pressure level with and without the sound absorbing material were the same, but the tendency was not the same in the actual vehicle. This is probably because the test piece covered 89% of the total, but 4.4%, so the effect was small.

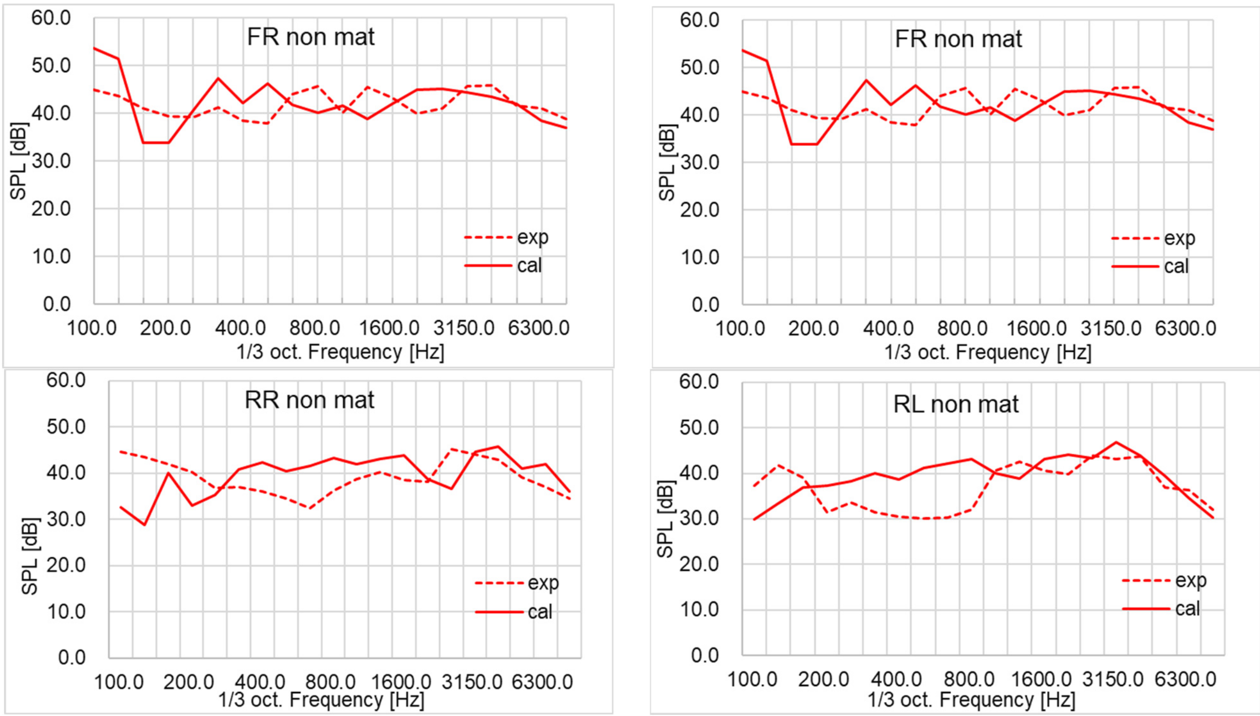


Fig. 13. Comparison of experimental and calculation results for sound pressure level by car.

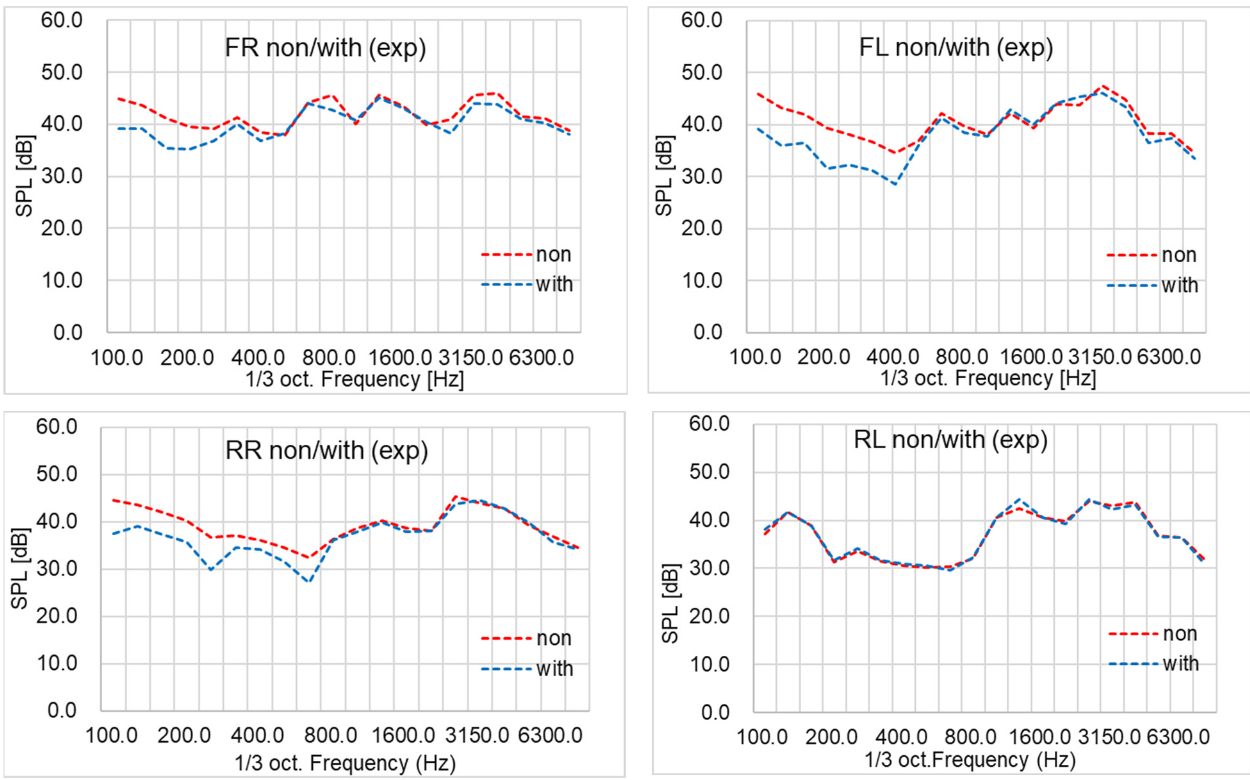
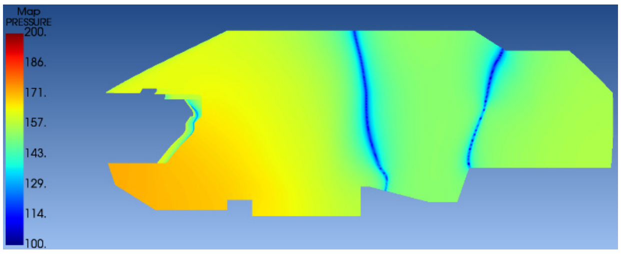
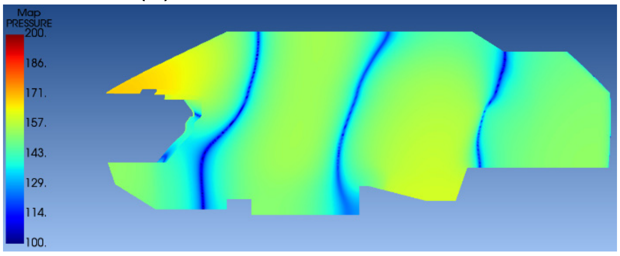


Fig. 14. Comparison of non/with PET for sound pressure level by car (experimental results).

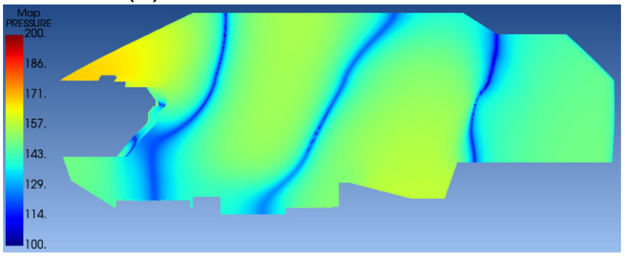


(a) non PET at 100 Hz

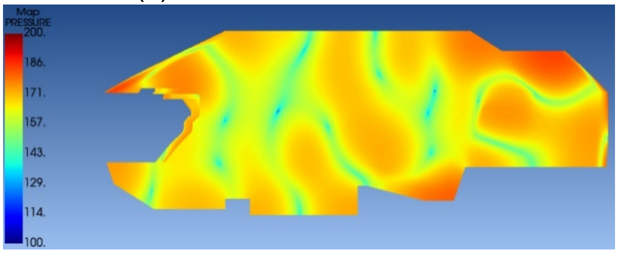
(b) with PET at 100 Hz



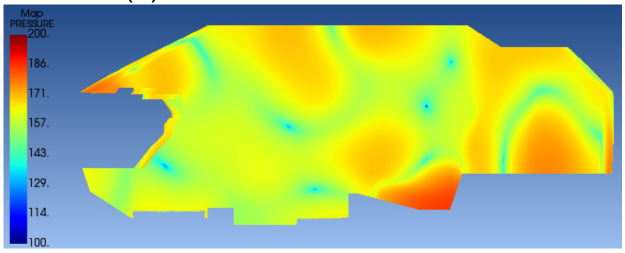
(c) non PET at 200 Hz



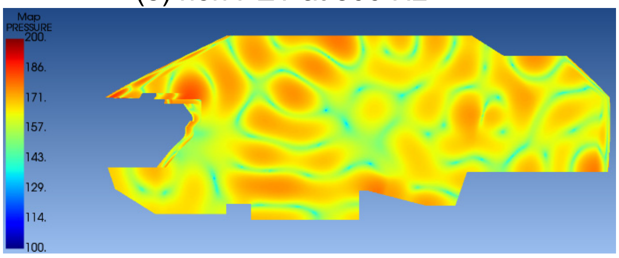
(d) with PET at 200 Hz



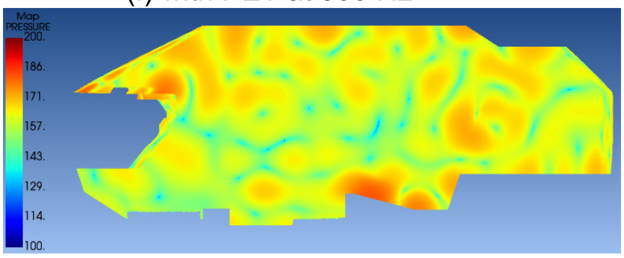
(e) non PET at 500 Hz



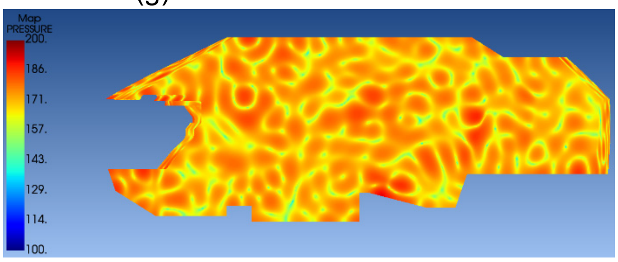
(f) with PET at 500 Hz



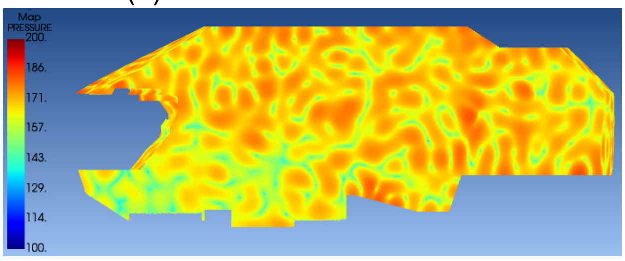
(g) non PET at 1000 Hz



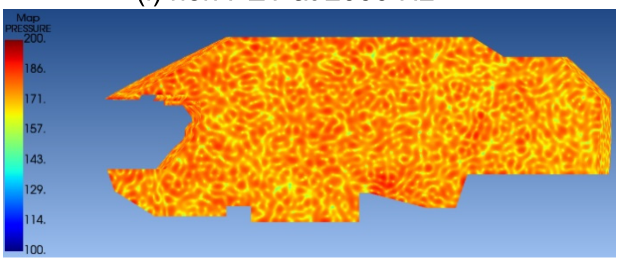
(h) with PET at 1000 Hz



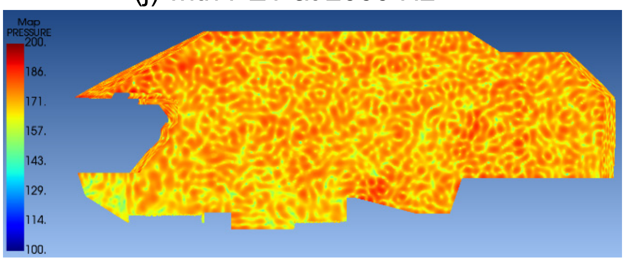
(i) non PET at 2000 Hz



(j) with PET at 2000 Hz



(k) non PET at 5000 Hz



(l) with PET at 5000 Hz

Fig. 15. Comparison of non/with PET for Sound pressure distribution on the wall.

Fig. 15 shows the sound pressure distribution on the wall surface at the main frequencies. The red part is the part where the sound pressure is high, and the blue part is the part where the sound pressure is low. All Fig. s have the same scale. There was a difference in the sound pressure distribution from 100 Hz, and it was confirmed that the sound pressure was small near the added PET material.

4. Conclusion

In order to analyze how the sound emitted from the car speaker changes due to the influence of the wall, in the case of a rectangular parallelepiped (inner size 600 mm × 600 mm × 630 mm) box with or without wall sound absorbing material (GW with a thickness of 50 mm) was calculated by experiments and FE model. The calculation results were able to roughly reproduce the experimental results. We also confirmed that the sound pressure level changes by about 20 dB above 500 Hz with and without GW.

Next, we created a simple FE model that simulates the interior space of a car, and the effects of sound absorption on the ceiling, floor, seats, etc., and the sound pressure level and sound when a sound absorbing material (PET material with a thickness of 50 mm) is added. The changes in the pressure distribution were measured using an actual vehicle (Lexus UX) and analyzed by the FE model. It was confirmed that the sound pressure distribution differs from 100 Hz with and without PET. In the future, we will improve the analysis accuracy by improving the recall rate of the passenger compartment shape and devising FE modeling.

References

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