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Effects of Acoustic Dissipative Material in Applications with Acoustic Leakage

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Abstract

This paper investigates the performance of a dissipative material compared to conventional acoustic materials under conditions that simulate real-world vehicle applications with acoustic leakage. Various acoustic materials were evaluated through laboratory experiments, which included acoustic leakage in both the steel panel and the acoustic materials. Acoustic leakages commonly occur in actual vehicle conditions at pass-throughs or fastener mounting locations. The study also presents in-vehicle test results to demonstrate the effectiveness of the dissipative material in managing acoustic leakage.

Introduction

Traditional barrier systems often require numerous holes or cutouts to provide access for electronics and mechanical systems. These openings in NVH (Noise, Vibration, and Harshness) barrier systems allow noise to penetrate through, affecting the cabin's acoustic environment. This issue is prevalent in all types of vehicles, whether they are traditional internal combustion engine (ICE) vehicles, hybrids, or electric vehicles (EVs). Regardless of the powertrain, NVH and interior designers have long sought dissipative materials that can function both as barriers and absorbers.

Lightweight materials contribute to increased fuel efficiency and/or battery life, while thinner acoustic materials can enhance interior space. Heavier acoustic materials typically offer higher acoustic absorption and transmission loss. However, the necessity of having holes in these treatments can lead to noise leakage.

Dissipative materials have proven effective in mitigating noise leakage in such systems. Barrier systems are commonly used in areas like instrument panels and inner and outer dash systems. Traditional absorbers manage leakage well but at the cost of low-frequency transmission loss. Conversely, effective barrier systems excel in transmission loss but perform poorly as absorbers, allowing noise to pass through the holes.

A dissipative absorber/barrier system offers significant advantages in both absorption and transmission loss, along with improved leakage management. This paper introduces a dissipative acoustic material that excels in leakage management compared to other systems. It includes performance evaluations in real vehicle applications and component lab testing.

Plate Test

We evaluated the differences in sound transmission loss performance with and without holes for shoddy material, which is a sound-absorbing material, heavy barrier rubber material, and dissipative material.

Experimental Setup for Plate Transmission Loss

TABLE 1 Material properties of acoustic materials for evaluation.

Material	Surface Density [g/m^2]	Thickness [mm]
Dissipative Material	900	12.0
Shoddy	1000	8.0
Heavy barrier rubber material	4000	3.0

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A 60 mm hole was made at the center of a 0.8 mm steel plate on the reverberation room side as shown in Figure 1. A loudspeaker in the reverberation room generated white noise and a microphone measured the source room level to calculate the transmission loss.

Three different hole diameters at 30 mm, 60 mm and 90 mm were used in the 500 × 500 mm acoustic materials at the bottom left of the anechoic chamber side

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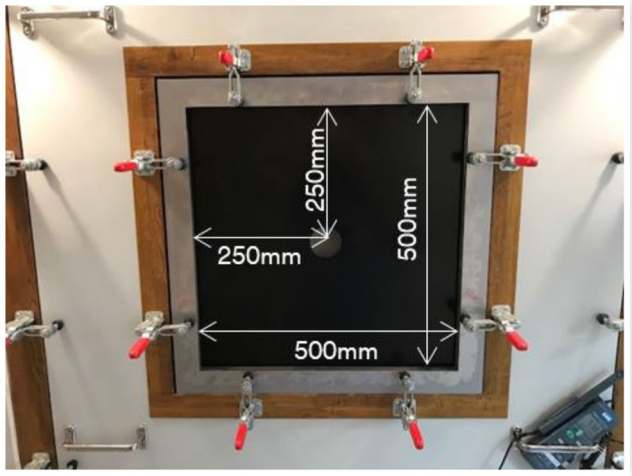
FIGURE 1 Reverberation chamber side window (500mm × 500mm).



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as shown in Figure 2. The hole was located on the bottom left corner, and it is 100 mm from the bottom and side walls.

The measurement points are 100 mm from the material surface. A total of 16 points (4×4) were measured with an acoustic intensity probe. The test was done per ISO 15186-1 [1].

Note that there is a 50 mm air gap between the steel panel and the acoustic material. Figure 3 shows the noise path from the source room to the receiving room through the steel panel and acoustic material with leakage.

Plate Test Experimental Results

In Figure 4, the result for the sound transmission loss is shown. Shoddy has lower soundproofing performance compared to the dissipative material, so its performance is inferior even at the same weight. The heavy barrier material (rubber plate) performs well if there are no holes, but its performance decreases as the open area increases.

FIGURE 2 Anechoic chamber side window.

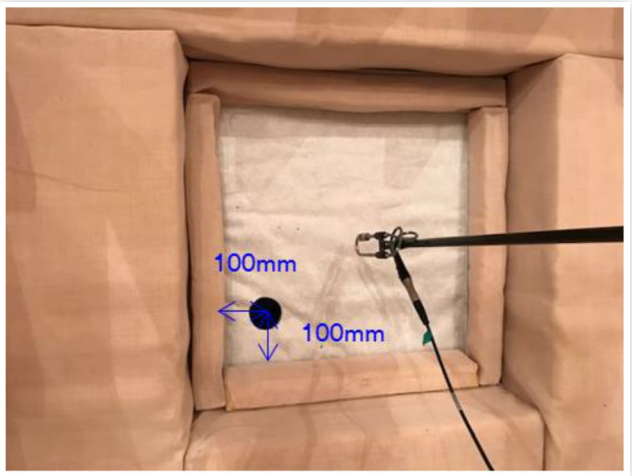

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FIGURE 3 Noise path from the source room to the receiving room.

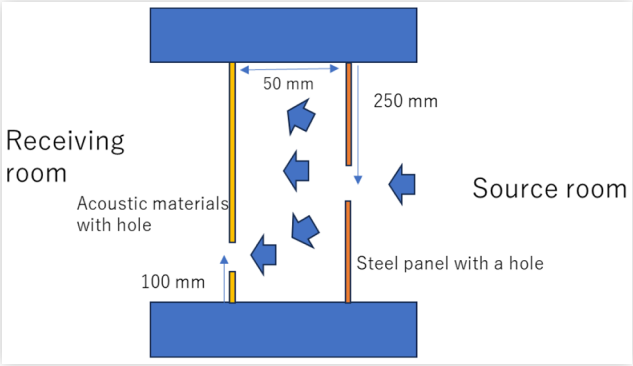

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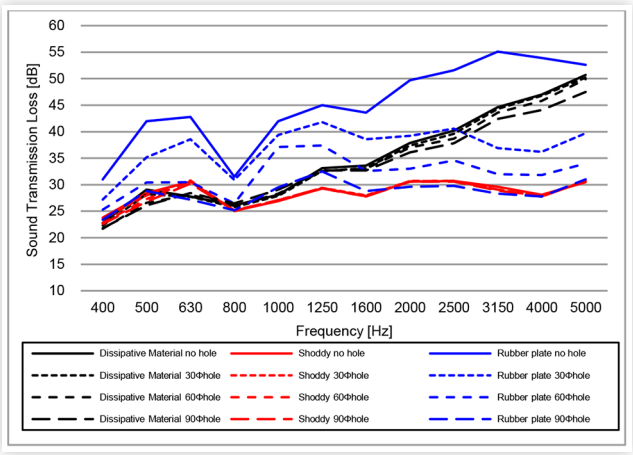
FIGURE 4 Sound transmission loss performance with and without holes for sound-absorbing materials (Shoddy 1000 g/m^2, 8 mm), barrier materials (Rubber plate 4000 g/m^2, 3 mm), and dissipative materials (900 g/m^2, 12 mm).



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If the hole diameter is 90 mm, the performance of the dissipative material surpasses that of the rubber plate.

In-Vehicle Tests

Acoustic testing was performed with a mid-sized SUV vehicle to identify how the dissipative material works compared to other conventional acoustic materials in an actual vehicle. Applications and acoustic materials tested are shown in Figure 5 and Tables 2 and 3.

The instrument panel (IP) and rear wheel arch panel are chosen for this study because acoustic leakage is likely to exist in both applications.

In-Vehicle Materials and Experimental Setup

Note that the fibrous acoustic absorption materials shown in Table 3 are low density acoustic absorption materials

FIGURE 5 Application areas.

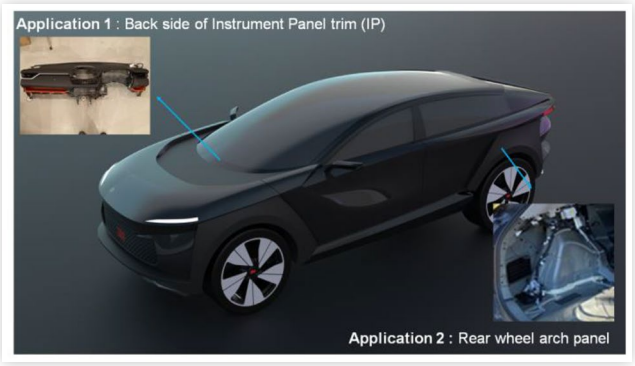

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TABLE 2 Application areas.

Application 1	Instrumental Panel (IP)
Application 2	Rear Wheel Arch Panel

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made of fibers that have high acoustic absorption, but low transmission loss. The dissipative materials used in Table 3 have higher density than the fibrous acoustic absorption materials and they have high acoustic absorption and good transmission loss. The fibrous acoustic absorption materials have higher thickness than the dissipative materials.

The instrument panel is close to the front wall in which many pass-throughs exist for cables and hoses. Although often those pass-throughs are sealed, they may not be fully sealed. These pass-throughs work as acoustic leakages.

For the rear wheel arch panel, there are pressure release valves to release pressure when opening and closing the car doors. Moreover, when the air recirculation mode is not selected in the HVAC controls, the pressure release valves are open, and the air comes in from outside and vents through the pressure release valves. The valves are made of thin rubber panels and sound can move through the material or leak through the gap.

TABLE 3 Material properties of the acoustic materials evaluated.

Material	Surface Density [g/m²]	Thickness [mm]
Dissipative material 1	900	12.0
Dissipative material 2	500	5.5
Dissipative material 3	370	4.5
Fibrous acoustic absorption material 1	442	26.0
Fibrous acoustic absorption material 2	242	13.0
Fibrous acoustic absorption material 3	332	41.0
Decoupled material 1 (Dissipative material 3 + Fibrous acoustic absorption material 2)	612	17.5

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Vehicle test conditions:

Noise source: Volume Velocity Source (VVS)

Microphone: 1/2 inch, random incidence microphone

Analyzer: B&K Pulse

In this test, a volume velocity source (VVS) with white noise was used as the noise source and the average of the noise transfer function between multiple positions of the VVS and the microphones was used for the different materials. All the tests were done inside of a large hemi-anechoic chamber.

For the instrument panel application, the VVS was put in the engine compartment at four different locations, as shown in Figure 6, to simulate the noise coming from the engine room. The four blue dots indicate the locations of the noise source. Inside the vehicle, two microphones were set at the driver and passenger head locations to check the effect of various acoustic materials in the instrument panel; the locations are marked with red arrows in Figure 6.

For the rear wheel arch panel test, the VVS was put at the rear tire right and left locations and two microphones were set at the rear passenger seat to check the effect of various acoustic materials used in the rear wheel arch panel as shown in Figure 7.

For the evaluation, the average transfer function between the noise source and the receiver was used to compare the performance of various acoustic materials.

For the instrumental panel application, two pieces of acoustic materials were used at the driver and passenger sides, as shown in Figure 8. The size of the left part was 120 × 60 cm, and the right part was 50 × 50 cm. There are some noise leakages in this application. HVAC pipes and a steering wheel shaft go through the dash panel and near these parts, at least three holes, 20-50 mm in diameter, exist in both the firewall and inner dash acoustic part. Engine noise will transfer into the IP area through the holes. An acoustic absorber has been applied traditionally to reduce the noise transfer through the dash panel. Often, the transmission loss function of the acoustic

FIGURE 6 Two microphones at the front seats are marked with red arrows and the four locations of the VVS in the engine compartment are marked with blue circles.

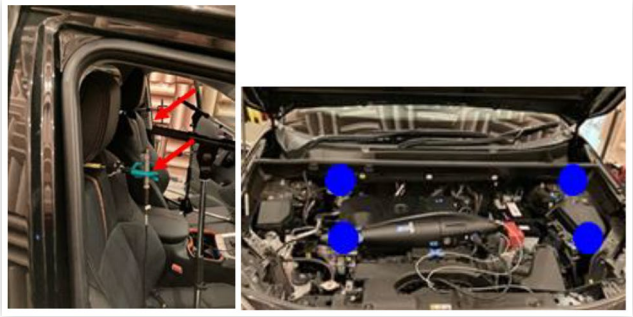

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FIGURE 7 Microphones at the rear seat (red arrows) and the VVS at the rear tire (blue dots).



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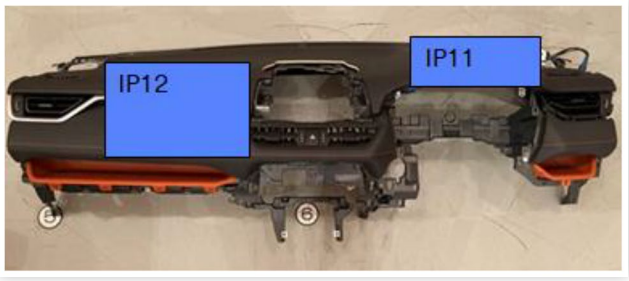
FIGURE 8 Acoustic materials in the instrument panel.



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material was not considered a performance requirement.

In-Vehicle Experimental Results

The transfer function results are shown in Figure 9, and the frequency averaged transfer functions are compared in Table 4.

The acoustic absorption performance and the sound transmission loss (STL) performance for each material are shown in Figures 10 and 11. The tests were done per SAE J2883 [2] and per ASTM E2611 [3], respectively. Note that the transmission loss test was performed with acoustic material only without substrate material.

The acoustic absorption performance of Dissipative material 2 and Fibrous acoustic material 2 is similar. Examples of both materials are illustrated in Figure 12. However, Dissipative material 2 exhibits significantly higher sound transmission loss compared to Fibrous acoustic material 2. Generally, dissipative acoustic

TABLE 4 Noise level reduction from baseline for the instrument panel.

Property	Dissipative material 2	Fibrous acoustic material 2	Baseline (No IP or covers)
Area [m^2]	0.58	0.58	-
Weight [g]	290	140	-
Thickness [mm]	5.5	13	-
Average: 250 Hz to 5 kHz	-0.7	-0.3	-
Average: 250 Hz to 1 kHz	-0.6	0.0	-
Average: 1 kHz to 5 kHz	-0.9	-0.7	-

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FIGURE 10 Random incidence acoustic absorption performance.

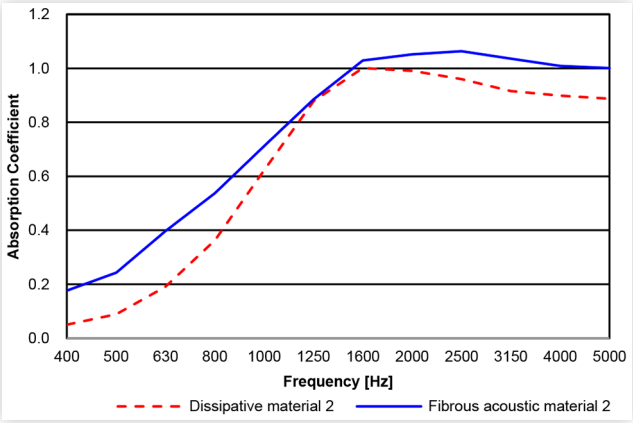

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FIGURE 9 Instrument panel test result (lower is better).

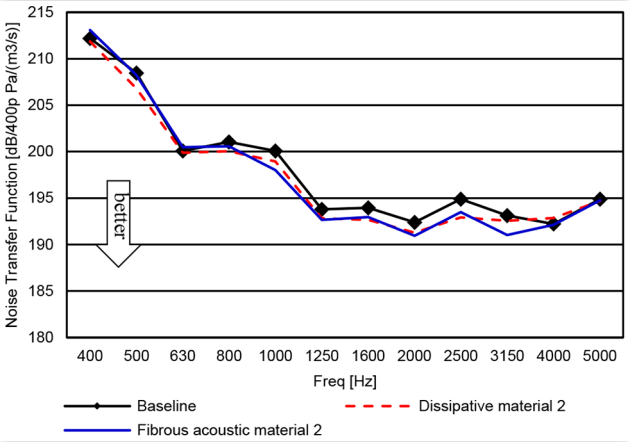

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FIGURE 11 Sound transmission loss performance.

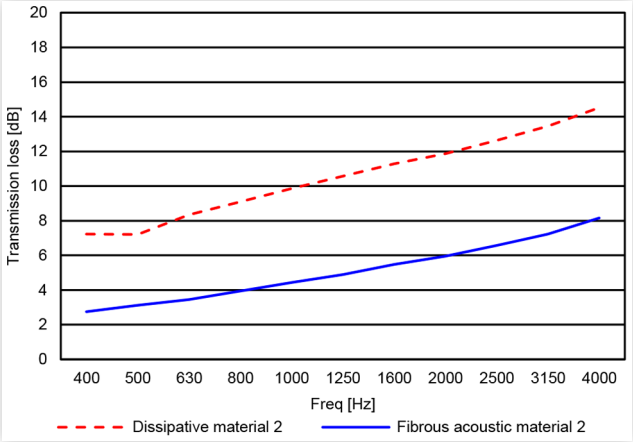

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FIGURE 12 Pictures of fibrous acoustic material (left) and dissipative material (right).



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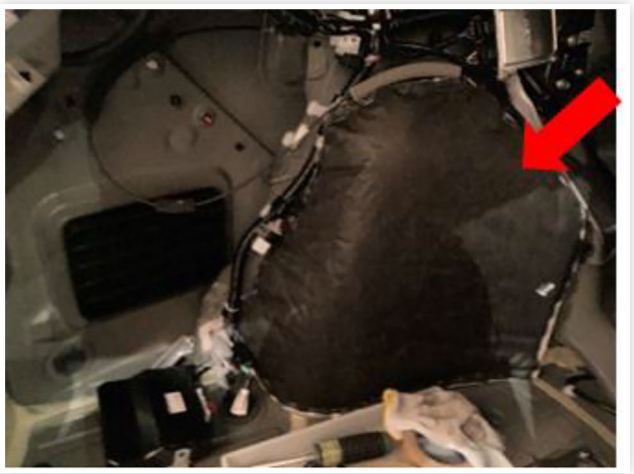
materials possess a higher surface density than fibrous acoustic materials. Additionally, dissipative materials are thinner than fibrous acoustic materials, as shown in Table 3. Consequently, dissipative materials have a high density combined with high airflow resistance. The dissipative materials discussed in this paper are composed of microfibers and acoustic particles, while fibrous materials are composed of microfibers and macrofibres. These materials were previously introduced at the SAE NVH conferences [4,5].

As seen in Figure 9 and Table 4, Dissipative material 2 shows higher noise reduction than Fibrous acoustic material 2 over the whole frequency range. Higher noise reduction was found at 250 – 1000 Hz. The reason why Dissipative material 2 has higher performance in this application may be that it has higher transmission loss performance and good acoustic absorption performance. That contributes to improved acoustic leakage management. Fibrous acoustic material 2 has good acoustic absorption performance but poor transmission loss performance. Because there is significant acoustic leakage in this application, having lower transmission loss caused lower performance.

For the rear wheel arch panel, one piece of the material was used as shown in Figure 13 by the red arrow. Since the part is not molded, a small gap between the body-in-white panel and the material exists. Additionally, the pressure release valve is in the body structure, right next to the wheel arch panel.

FIGURE 13 Acoustic material at rear wheel arch panel.



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The transfer function spectra are shown Figure 14. Frequency averaged transfer functions are compared in Table 5. Fibrous acoustic material 3 on the luggage side trim (LST) was removed when the acoustic material on the wheel arch panel was used in the test.

The decoupled material was also evaluated in this application. Decoupled material 1 is made of a combination of Dissipative material 3 and Fibrous acoustic material 2. This provides a solution of similar weight and significant acoustic improvements. The noise leakage performance of this material enables the improvements.

Dissipative material 1 can provide the highest acoustic improvement due to its high sound transmission loss and noise leakage management.

As shown in the Table 5, Fibrous acoustic material 1 can achieve a lightweight solution, reducing weight from

FIGURE 14 Wheel arch panel test (lower is better).

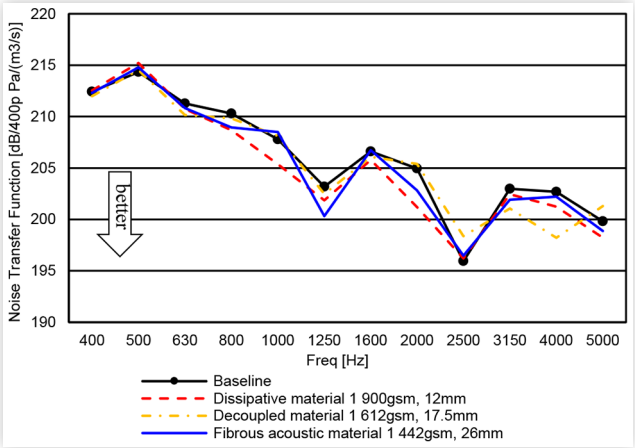

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TABLE 5 Noise level reduction from baseline for wheel arch panel.

Property	Decoupled material 1 612 gsm 17 mm	Dissipative material 1 900 gsm 12 mm	Fibrous material 1 422 gsm 26 mm	Baseline
Area [m^2]	0.22	0.22	0.22	0.33
Weight [g]	135	198	97	110
Thickness [mm]	17.5	12	26	41
Ave. 250 Hz to 5 kHz	-0.9	-1.0	-0.5	-
Ave. 250 Hz to 1 kHz	-0.7	-0.7	-0.1	-
Ave. 1 kHz to 5 kHz	-0.9	-1.5	-0.8	-
Wheel arch panel	Present	Present	Present	None
Luggage side trim	None	None	None	Present

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110 g to 97 g, with 0.5 dB acoustic improvement for 250 – 5000 Hz, compared to the baseline. In general, when the acoustic material is located close to the noise source, the acoustic part can work better than a part located further away from the noise source. For the baseline, the acoustic part was attached to the quarter trim panel which was further away from the noise source. Decoupled material 1 and Dissipative material 1 have higher absorption and transmission loss performance than Fibrous acoustic material 1. As a result, these materials provided higher acoustic performance in the vehicle test.

Discussion

In the plate test, shoddy material demonstrated inferior performance compared to dissipative material, even when matched for weight. While heavy barrier material performed well in the absence of holes, its effectiveness diminished as the open area increased. Despite being much lighter, the dissipative material outperformed the rubber plate. For small holes, it surpassed the plate at high frequencies, and as the hole size increased, the dissipative material proved superior at progressively lower frequencies. This was attributed to the plate's performance declining while the dissipative material's performance remained relatively constant.

Similarly, in the in-vehicle tests, dissipative and decoupled materials, which possess both barrier and absorption capabilities, outperformed fibrous materials that have significantly lower barrier performance but similar absorption properties. The barrier material was not tested in the vehicle because the molded barrier part was not available for this specific vehicle. It is anticipated that the results would be similar to those observed in the plate test, and it would be beneficial to include this in future research.

In both the plate test and the in-vehicle tests involving the instrument and rear wheel arch panels, it was observed that the use of dissipative materials enhances transmission loss in scenarios with acoustic leakage. Acoustic leakage allows noise to bypass the barrier performance of acoustic treatments, making the absorption capability of dissipative materials near the leaks particularly advantageous.

Summary/Conclusions

The plate test, which included a hole in both the substrate and the acoustic materials, demonstrated that the dissipative material experiences only a minimal reduction in transmission loss, whereas conventional barrier material shows a substantial drop in performance. In-vehicle tests were conducted using various types of acoustic materials for two applications involving acoustic leakage. The dissipative material performed well in these scenarios due to its effective acoustic leakage management and high acoustic dissipation capabilities. This high acoustic performance, combined with its lightweight nature, will enhance passenger comfort and contribute to energy savings. Additionally, the lightweight material can improve workability for OEMs during assembly.

References

1. ISO, *Acoustics – Measurement of sound insulation in buildings and of building elements using sound intensity*, ISO 15186-1, Published 2000.
2. SAE International Surface Vehicle Recommended Practice, *Laboratory Measurement of Random Incidence Sound Absorption Tests Using a Small Reverberation Room*, SAE Standard J2883, Revised. March 2020.
3. ASTM, *Standard Test Method for Measurement of Normal Incidence Sound Transmission of Acoustical Materials Based on the Transfer Matrix Method*, ASTM Standard E2611-09. Revised June 2024.
4. Yoo, T., Gerdes, R., and Shi, T., "A Novel Dissipative Acoustic Material," SAE Technical Paper, 2021-01-1128 (2021), https://doi.org/10.4271/2021-01-1128.
5. Yoo, T., Gan, K., Herdtle, T., and Anderson, B., "A Lightweight Multilayer Dissipative Material with High Acoustic Performance," SAE Technical Paper 2023-01-1083 (2023), https://doi.org/10.4271/2023-01-1083.

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