Reduction of Noise Generated from Lower Part of Shinkansen Cars with Sound-Absorbing Panels

Yoshiki KIKUCHI¹, Takeshi KURITA¹, Haruo YAMADA¹ and Atsushi IDO²
¹R&D Center of JR East Group, East Japan Railway Company, Saitama, Japan
²Railway Technical Research Institute, Tokyo, Japan (Former, East Japan Railway Company)

Abstract

In order to reduce Shinkansen wayside noise at higher speeds, it is necessary to reduce not only pantograph noise but also noise from the lower part of cars. After pantograph noise, lower-part noise is the greatest contributor to the overall noise level in Series E2-1000 (a presently-operating commercial Shinkansen train with a maximum speed of 275 km/h in JR-East) running at a speed of 360 km/h. Therefore, with the aim of absorbing noise from the lower part of the car body through a process of multiple sound reflections between the car body and a noise barrier, we developed sound-absorbing panels for the lower sides and underside of the car bodies. First, in order to investigate the relation between sound absorption surface area and noise reduction effect by the panels, we conducted acoustic tests using a full-scale cut car model. The test results were adjusted to noise levels from the lower part of cars both with and without the panels using data taken from near the rail on which a Series E2-1000 train was running at 360 km/h. Effectiveness in noise reduction in a frequency range of 500 to 4000Hz was confirmed. Based on these results, we installed the sound-absorbing panels to the lower parts of "FASTECH360S", a high-speed test train of JR-East. To evaluate panels’ effect on noise reduction, we conducted running tests using FASTECH360S both with and without sound absorption at higher speeds. As a result, the sound-absorbing panels reduced the noise level at a point 25 meters from the center of the track and 1.2 meters above the ground by an average of roughly 1 dB.

1. Introduction

Cutting Shinkansen travel time is the most effective way to increase market share. To shorten travel times, it is required to increase the maximum speed of Shinkansen trains. Since 2002, East Japan Railway Company has been working on the development of technologies to raise the maximum operating speed of Shinkansen to 360 km/h[1]. This makes it much more important to reduce wayside noise, which necessarily increases with speed. In order to reduce Shinkansen wayside noise at higher speeds, it is necessary to reduce not only pantograph noise but also noise from the lower part of cars. After pantograph noise, lower-part noise is the greatest contributor to the overall noise level in Series E2-1000 (a presently-operating commercial Shinkansen train with a maximum speed of 275 km/h in JR-East) running at a speed of 360 km/h[2]. Therefore, with the aim of absorbing noise from the lower part of the car body through a process of multiple sound reflections between the car body and a noise barrier, we applied sound-absorbing panels to the lower sides and underside of the car bodies.

First, in order to investigate the relation between sound absorption surface area and noise reduction effect by the panels, we conducted acoustic tests using a full-scale cut car model. Next, based on the results, we installed the panels to the lower part of "FASTECH360S", a high-speed test train of JR-East. To evaluate the effectiveness in noise reduction of the panels, we conducted running tests using FASTECH360S both with and without sound absorption at higher speeds. In this paper, the steps of development of the panels for Shinkansen trains are explained and their effectiveness in noise reduction is also discussed.

2. Measures for Reducing Noise from Lower Part of Cars

Noise sources in a running Shinkansen train can be divided into five components (Fig.1): pantograph noise, noise from lower part of cars, noise from upper part of cars, aerodynamic noise from train nose, and structure-borne noise. Since noise from the lower part is the second largest source of overall noise in Series E2-1000 running at 360 km/h, in order to effectively reduce wayside noise, it is necessary to reduce noise from the lower part of the cars. Therefore, with the aim of absorbing noise from the lower part of the car body through a process of multiple sound reflections between the car body and a noise barrier, we make an attempt to apply sound-absorbing panels to lower sides and
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underside of the car bodies, as shown in Fig.2.

![Fig. 1 Noise sources of Shinkansen](image)

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![Fig. 2 Sound absorption through a process of multiple sound reflections between car body and noise barrier](image)

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3. Development of Sound-absorbing Materials

To absorb noise emitted from the lower part of cars and from the ground, sound-absorbing materials were developed and placed in strategic locations on the lower side and bottom of the car body. To estimate the effects of these materials, it is important to estimate the level of noise reduction along the railroad line. For this purpose, acoustic tests were carried out using a full-scale cutting car model.

3.1 Full-scale cut car model for acoustic tests

Figure 3 shows the equipment used in the acoustic tests, consisting of a full-scale Shinkansen car model (6 m in length) with enough space for one bogie and a concrete noise barrier (5 m in length). Noise from the lower part of cars consists of rolling noise from wheels/rails and aerodynamic noise from the parts themselves. In the acoustic tests, these noises were reproduced using speaker sets (consisting of two speakers facing away from each other) in four locations. Where noise was thought to stem from the wheels (referred to as “wheel position noise source”), the speakers were located at the same height as the center of the wheel. For noise sources from rails (“rail position noise source”), they were located near the top of the rail.

Microphones were placed on the inside and outside of the noise barrier, with the inside microphone located in the same position as tests for actual Shinkansen cars. As it was not possible to put the outside microphone at the distance of 25 m usually implemented for measurement of Shinkansen noise, it was placed 5 m away from the noise barrier at a height of 1.2 m.

The area fitted with sound-absorbing materials is shown in Fig. 4 (a) and (b). The materials (referred to as “sound-absorbing panels”) were installed on the inside of the bogie space and on under-floor covers, side skirts and sides of the car body. As “pink noise” was used in testing to reproduce noise emitted from the lower part of cars and from the ground, the test results obtained had to be corrected using sound measured from actual Shinkansen cars (series E2-1000 at 360 km/h).
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Fig. 3 Experimental Apparatus of Full-scale Car model used for acoustic tests

Fig. 4 (a) Areas installed with sound-absorbing panels (Shaded area: sound-absorbing materials) in sectional and side views
3.2 Sound-absorbing materials

Estimation was carried out with three types of sound-absorbing material using the experimental equipment outlined above. Figure 5 shows these materials:

- Type 1: Aluminum fiber + resonance structure
- Type 2: Perforated plate + porous material + honeycomb
- Type 3: Aluminum fiber + air layer

Figure 6 shows the results of acoustic tests using these materials. For both the rail position noise source and the wheel position noise source, Type 2 had the highest sound-absorbing performance; thus these materials were selected.
3.3 Sound-absorbing area

To study the relation between the sound-absorbing surface area and the sound reduction effects, the sound-absorbing surface area was changed and the sound level measured. Figure 7 shows the results of the outside sound level tests. In both the rail position noise source and the wheel position noise source, the effectiveness of sound reduction improves with increases in the sound-absorbing surface area. It was found that, up to a sound-absorbing surface area ratio of about 50%, sound levels were significantly reduced.

![Graph showing relation between sound-absorbing surface area and sound reduction effects](image)

- (a) Rail position noise source
- (b) Wheel position noise source

Fig. 7 Relation between the sound-absorbing surface area and sound reducing effects

(Outside microphone)

3.4 Sound-absorbing panels for FASTECH360S

Sound-absorbing panels were improved (Fig. 8) for sufficient durability to be used on the FASTECH360S. In the tests, the installation area was simulated as shown in Figure 4 to represent the limited sound-absorbing panel installation area of the FASTECH360S. Figure 9 shows the results of the outside sound level tests. Sound levels were reduced in a frequency range of 315Hz and above, and notable reduction was seen in particular between 500Hz and 4000Hz. The overall sound level was reduced by 2.8 dB (rail position noise source) and 3.2 dB (wheel position noise source).

![Diagram of sound-absorbing panel structure](image)

Fig. 8 Sound-absorbing panel structure of FASTECH360S

![Graph showing acoustic test results of sound-absorbing panel for FASTECH360S](image)

- (a) Rail position noise source
- (b) Wheel position noise source

Fig. 9 Acoustic test results of sound-absorbing panel for FASTECH360S
4. Onboard Test

4.1 Installation of sound-absorbing panels on FASTECH360S

As described in Chapter 2, noise from the lower part of cars is the second largest cause of noise in Series E2-1000 running at 360 km/h. Hence, reduction of noise from this area is an important issue in reducing overall noise. We thus installed bogie side skirts which shielded under-floor equipment and wheels on FASTECH360S, as shown in Fig.10. In order to reduce noise from the lower part of car body resulting from multiple noise reflection between car body and noise barrier, we also applied sound-absorbing panels to the car bodies (Fig.11 (a) and (b), Fig.12).

![Fig. 10 Bogie side skirts](image)

![Fig. 11 Sound-absorbing panels for lower side and underside of cars](image)

![Fig. 12 Sound absorption area](image)

4.2 Comparison between sound levels with and without sound-absorbing panels

In order to evaluate the effectiveness of noise reduction in sound-absorbing panels, we conducted two running tests with FASTECH360S, one with and one without sound absorption. Figure 13 shows noise levels measured at 25 meters away. As a result, the sound-absorbing panels reduced noise levels at 25 meters by an average of roughly 1dB.

![Fig. 13 Comparison of A-weighted sound pressure levels (at 25 meters) between with and without sound absorption](image)
5. Conclusion

In order to reduce the noise from the lower part of Shinkansen cars, we developed sound-absorbing panels for FASTECH360S. Firstly, we compared the sound reduction performance of 3 types of sound-absorbing materials, and concluded Type 2 (perforated plate + porous material + honeycomb) had the best performance. Secondly, we developed sound-absorbing panels with sufficient durability to be used on the FASTECH360S and confirmed their effectiveness in sound reduction by acoustic tests. Finally, we conducted running tests using FASTECH360S both with and without the sound-absorbing panels, and the results showed the noise levels at 25 m were reduced by an average of roughly 1dB. Based on the results of this development, the next generation Shinkansen trains, Series E5 and Series E6, will be equipped with sound-absorbing panels.

References