

Environmental Measures along Shinkansen Lines with FASTECH360 High-Speed Test Trains



Takeshi Kurita*



Fumio Mizushima*

JR East has been studying Shinkansen speed increases with a target of achieving 360 km/h operation speed. In the course of the study, we carried out running tests using FASTECH360 Shinkansen high-speed test trains from June 2005 to June 2009. In order to reduce wayside noise and tunnel micro-pressure waves, FASTECH360 trains are equipped with new noise reduction technologies such as new low-noise pantographs, pantograph noise insulation plates, noise-absorbing panels at the lower part of cars and circumferential diaphragms between cars. And they have nose shapes elongated up to 16 m long as a countermeasure against tunnel micro-pressure waves. After the start of the running tests, we continued improvement based on the measurement results of car noise sources acquired using a spiral microphone array.

As a result of introducing noise reduction technologies, we have been able to reduce wayside noise by 4 to 5 dB compared to the noise generated in coupled operation of series E3 and E2 trains. While we have not been able to reach the target speed of 360 km/h, still we have successfully operated the coupled train set at around 330 km/h at a noise level that is equal to the level of present trains in operation running at 275 km/h. In other words, noise at 330 km/h is no worse than the present level. For tunnel micro-pressure wave reduction performance, comparison of the two types of nose shape of FASTECH360S has demonstrated that tunnel micro-pressure waves were smaller with the "arrow-line" nose than with the "stream-line" nose. We also confirmed that tunnel micro-pressure wave reduction performance of the FASTECH360S (arrow-line nose, nose length: 16 m) and that of the FASTECH360Z (nose length: 13 m) are almost equal to each other.

●Keywords: Shinkansen, Noise, Microphone array, Pantograph, Aerodynamic noise

1 Introduction

One of the biggest issues in increasing Shinkansen speed is reduction of noise and tunnel micro-pressure waves. With a target of 360 km/h operation speed, JR East has developed two test train sets—the FASTECH360S (eight-car train set exclusive for Shinkansen) and the FASTECH360Z (six-car train set for through service on Shinkansen and conventional lines). We carried out running tests with those on the Tohoku Shinkansen line in the section between Sendai and Kitakami from June 2005 to June 2009 (April 2006 to September 2008 for the FASTECH360Z). In this article, we will introduce noise reduction measures, tunnel micro-pressure wave reduction measures and running test results for FASTECH360 (collective name for FASTECH360S and FASTECH360Z).

2 Noise Reduction

2.1 Running Tests at 360 km/h Using a Series E2-1000 Train

In advance of development of the FASTECH360, we carried out running tests at 360 km/h using a series E2-1000 train in the section between Urasa and Niigata on the Joetsu Shinkansen line to confirm the noise reduction target level. Noise sources on the Shinkansen while running are, as shown in Fig. 1, classified into five categories: pantograph noise, aerodynamic noise from the train nose, aerodynamic noise from the upper part of cars (aerodynamic noise between cars etc.), noise from the lower part of cars (wheel/rail noise, aerodynamic noise around bogies,

etc.) and structure-borne noise (noise generated from concrete viaducts). Based on the analyzing method of Nagakura¹⁾ and Kitagawa et al.²⁾, we estimated the amount of contribution of each component to overall noise 25 m from the track center with measurement data of series E2-1000 running at 275 km/h, 360 km/h and a low speed of 160 km/h. As shown in Fig. 2, the analysis results demonstrate that speed increase of E2-1000 from 275 km/h to 360 km/h increased overall noise by more than 6 dB. It also shows that noise from pantographs contributes to the overall noise in particular, followed by the noise from the lower part of the car body. We have hence confirmed that, for 360 km/h operation, significant reduction of noise from pantographs and from the lower part of the car body are required, with the total reduction needing to be more than 6 dB.

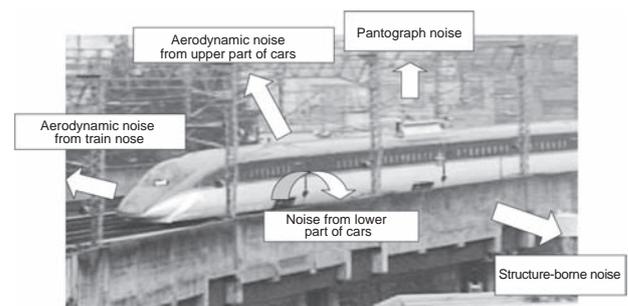


Fig. 1 Shinkansen Noise Sources

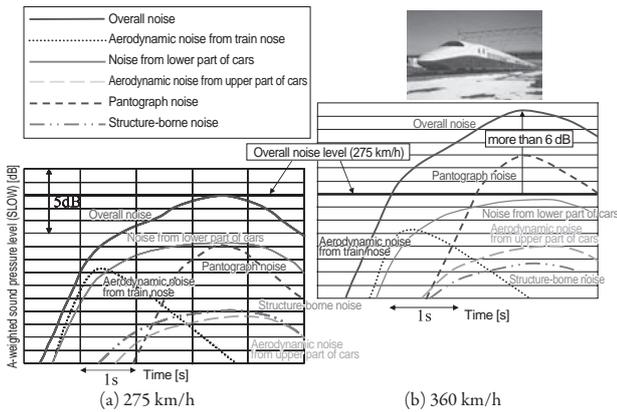


Fig. 2 Contribution of Noise Sources to Overall Noise at 25 m (Series E2-1000)

2.2 Overview of Measures for Noise Reduction on FASTECH360

In this section, we will give an overview of noise reduction measures for the FASTECH360S, in particular noise reduction at the pantographs and at the lower part of the cars that make large contribution to the overall noise. The FASTECH360Z is equipped with the same countermeasures as applied to the FASTECH360S, but some changes are added such as retractable pantograph noise insulation plates to keep within the rolling stock gauge of conventional lines.

2.2.1 Pantograph Noise

We installed two types of pantographs to the FASTECH360S: the type PS9037 pantograph (Fig. 4 (a)) that has the same main arm with intermediate hinge as the type PS207 (Fig. 3, installed to series E2-1000) and the type PS9038 pantograph that has no intermediate hinge (Fig. 4 (b))^{3) 4)}. Those are pantographs that have achieved noise reduction by improving the structure between the base frame windproof covers, the most conspicuous noise source of the type PS207 pantograph.

One of the two pantographs installed to a train set is folded and noise-insulated with pantograph noise insulation plates. Since that brings about a diffraction attenuation effect by hiding the folded pantograph behind the noise insulation plates, pantograph noise can be further reduced at the point of noise measurement. With an aim of achieving a larger diffracting attenuation effect, we initially installed pantograph noise insulation plates with a Z-shaped cross section (Fig. 5)^{3) 5)}.

Conventionally, a Shinkansen train collects current using two pantographs per train set (four pantographs in coupled operation) to prevent arcing that might be caused by contact loss. (Pantographs of each section of coupled train sets are not electrically connected to each other, while two pantographs in a train set are connected with a bus line). However, FASTECH360

is operated using only one pantograph per train set to collect current (Fig. 6, using the pantograph to the rear in terms of travel direction). Therefore, the pantograph for FASTECH360 must have significantly higher current collection performance than the PS207 to prevent contact loss as much as possible. Accordingly, we developed a multi-segment slider³⁾ (Fig. 7). Since the main contact strips (10 segments) are placed on a silicon rubber plate, segments are flexibly connected to each other and the slider has higher ability to follow the overhead contact line because of its smaller movable mass. Using that pantograph together with high tensile overhead contact lines achieves good current collection performance. Noise can thus be reduced by current collection using only one pantograph per train set.



Fig. 3 Type PS207 Pantograph

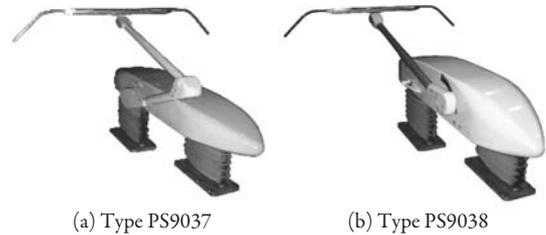


Fig. 4 New Low-noise Pantographs

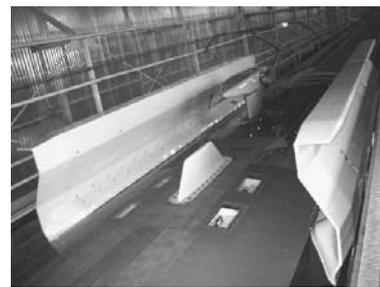


Fig. 5 Z-shaped Pantograph Noise Insulation Plates

2.2.2 Noise from the Lower Part of Cars

We installed bogie side covers of a height where the bottom surface of underfloor equipment is shielded on the FASTECH360S. In order to reduce the noise from the lower part of the car body

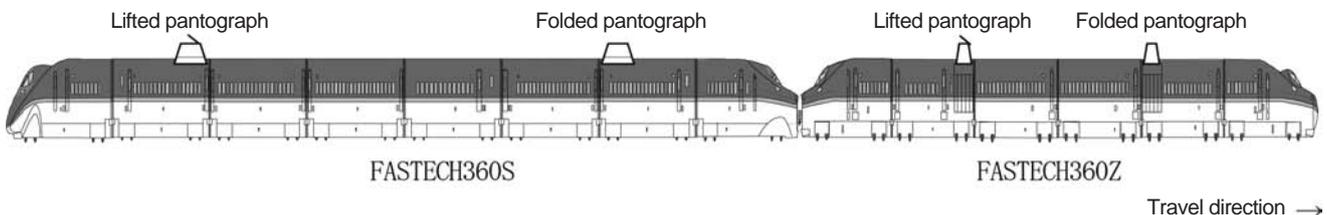


Fig. 6 Pantographs Used in Coupled Operation of FASTECH360Z and FASTECH360S (Northbound Train)

resulting from multiple noise reflection between car body and noise barrier, we also applied sound-absorbing panels¹⁾ to the car body (Fig. 8).

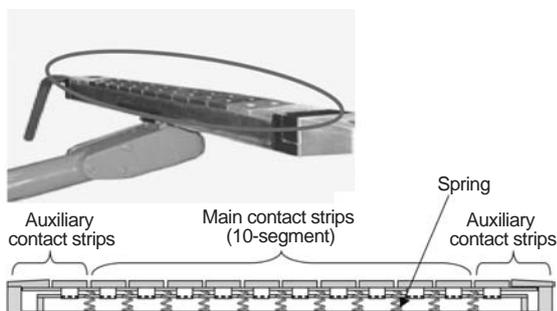


Fig. 7 Structure of Multi-segment Slider

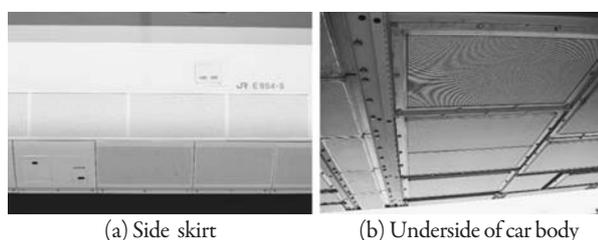


Fig. 8 Sound-absorbing Panels for Car Body

2.2.3 Aerodynamic Noise from the Train Nose

Noise from the train head mainly consists of aerodynamic noise from the head bogie, the handrail of the door of the crew cabin and the snowplow. We thus introduced bogie side covers, smoother handrails and snowplow covers (Fig. 9) to lessen that noise.

2.2.4 Aerodynamic Noise from the Upper Part of Cars

We developed circumferential diaphragms (Fig. 10) to reduce noise from the gaps between cars. The surface of doors and windows on the side are also smooth with the surface of the car body.



Fig. 9 Snowplow Cover



Fig. 10 Circumferential Diaphragms

2.3 Efforts in Noise Reduction after the Start of the Running Tests

2.3.1 Identification of Noise Sources and Study of Countermeasures

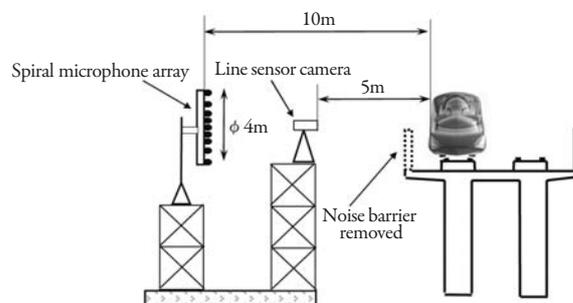


Fig. 11 Noise Measurement Using a Spiral Microphone Array

Fig. 11 and 12 show a schematic diagram of noise measurement using a spiral microphone array⁶⁾ and the measurement results respectively. Fig. 12 (a) shows the measurement results at the early stage of the running tests. That figure shows that much noise is generated at the rear end of the pantograph noise insulation plates as well as from some wheels and circumferential diaphragms. Therefore, we studied corrective measures for those noise sources.

We thought that wake vortices were the source of aerodynamic noise at the rear end of the pantograph insulation plates. We thus carried out running tests, introducing two measures to reduce the vertical correlation length of wake vortices. Those measures were

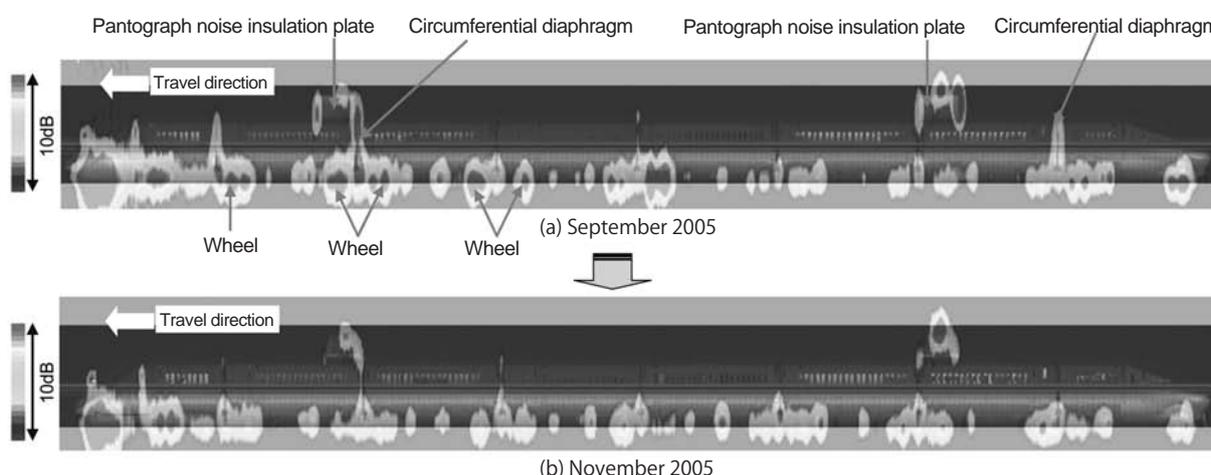


Fig. 12 Measurement Results of Noise Source Distribution for FASTECH360S (at Approx. 340 km/h, Noise Barrier Removed)

attaching vortex generators (small, semicircular protrusions, Fig. 13) and flat pantograph noise insulation plates with a 45 degree level at both ends of the plates viewed from the side that showed good results in past running tests of series E2-1000 cars⁷⁾ (Fig. 14, hereinafter “45 degree type flat pantograph noise insulation plates”). As shown in Fig. 12 (b), 45 degree type flat pantograph noise insulation plates showed better results in significantly reducing noise from the noise insulation plates themselves.



Fig. 13 Vortex Generators Added to Z-Shaped Pantograph Noise Insulation Plate



Fig. 14 45-Degree Type Flat Pantograph Noise Insulation Plates

For noise from the wheels (front half of the train set), we carried out running tests blocking the ventilation route for the cooling fins on the back of the brake disc on the side of the wheel. The tests results proved that noise could be reduced to the level at the other wheels as shown in Fig. 12 (b). In other words, the noise source was found to be aerodynamic noise from the cooling fins. As for noise from the circumferential diaphragms, we found that much noise was generated when air flowed into the thin gap of the diaphragm plates. Noise could therefore be reduced by blocking the gaps as shown in Fig. 12 (b).

2.3.2 Noise at 25 m from the Track Center

Fig. 15 and 16 respectively show the noise measurement overview and the measurement results using nondirectional microphones (dynamic characteristic: SLOW). Based on the results shown in Fig. 16, we gained a perspective in November 2005 that we would be able to improve the running speed of the FASTECH360S (noncoupled operation) to approx. 320 km/h at a noise level equivalent to that of present trains running at 275 km/h by applying the noise reduction measures in 2.3.1.

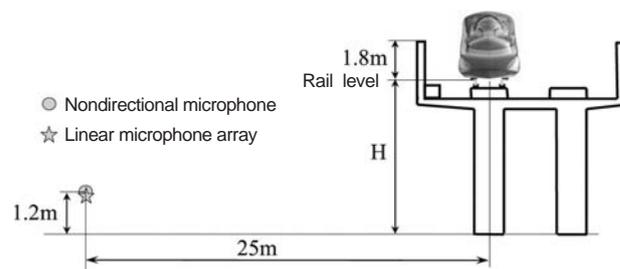
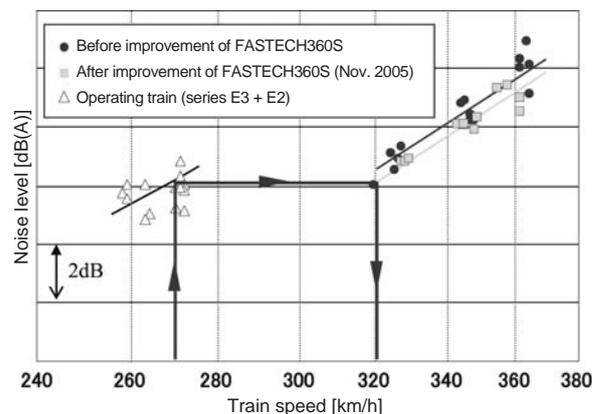
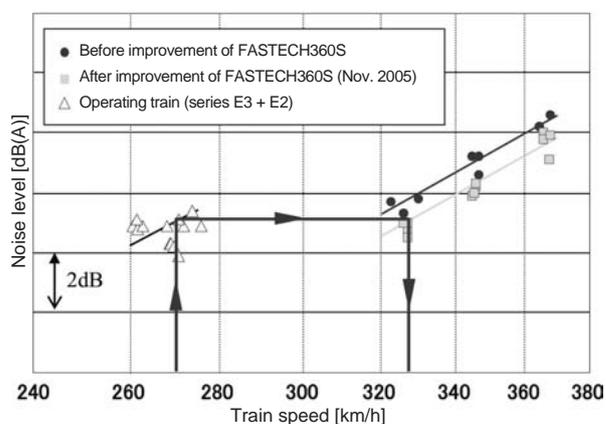


Fig. 15 Noise Measurement at 25 m around 374k300 (H = 9.0 m) and 387k750 (H = 9.4 m) on Tohoku Shinkansen



(a) Noise at 25 m (around 374k300 on Tohoku Shinkansen)



(b) Noise at 25 m (around 387k750 on Tohoku Shinkansen)

Fig. 16 Noise Measurement Results at 25 m (November 2005)

2.3.3 Improvements for Noise Reduction of FASTECH360

Based on the study explained in 2.3.1, we further improved noise reduction for the FASTECH360S. We carried out wind tunnel tests using a 1/10 scale model to find ways to reduce noise from pantograph noise insulation plates in March 2006. Based on the results, we replaced in July to September 2006 the plates with 30 degree type flat pantograph noise insulation plates that generate less noise (Fig. 17). In August 2006, we made both pantographs of a train set type PS9038 pantographs that have better noise reduction performance. From May through September 2006, we improved the shape of the cooling fins on the back of the brake disc on the side of the wheel (added ribs on the inner periphery

of the disc to reduce air flow through the fins) and improved the circumferential diaphragms (Fig. 18, changed the material of the middle of the three diaphragm plates to rubber and connected both end plates with rubber to block the gap where air enters).



Fig. 17 30-Degree Type Flat Pantograph Noise Insulation Plate



Fig. 18 Improved Circumferential Diaphragms

For the FASTECH360Z that started running tests in April 2006, we applied the same improvements as for the FASTECH360S. For example, we changed the angle of the front and rear ends of the retractable pantograph noise insulation plates from a right angle to 30 degrees (Fig. 19).

Comparing Fig. 16 (a) and (b), we can see that the noise reduction effect shown in (b) is around 1 dB, while the effect in (a) is around 0.5 dB. Since the effect of the improvement on FASTECH360 around 374k300 is relatively small, we deduced that structure-borne noise affected that smaller effect. In order to reduce the structure-borne noise, we replaced the track pad with a low-spring constant track pad (Fig. 20, static spring constant of 30 MN/m, half the usual track pad) in a 200 m section (100 m in each direction) at 374k300 in July 2006.

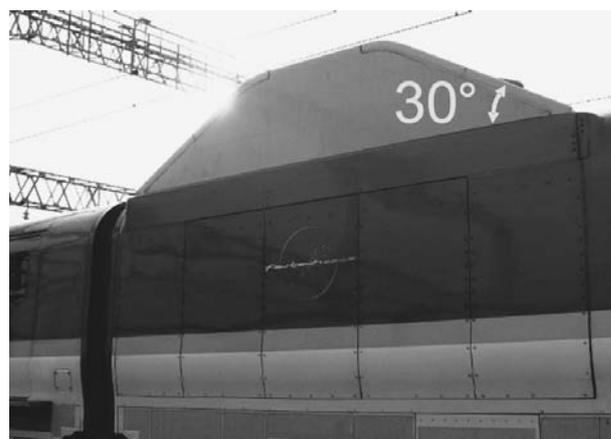


Fig. 19 Retractable Pantograph Noise Insulation Plate (FASTECH360Z)

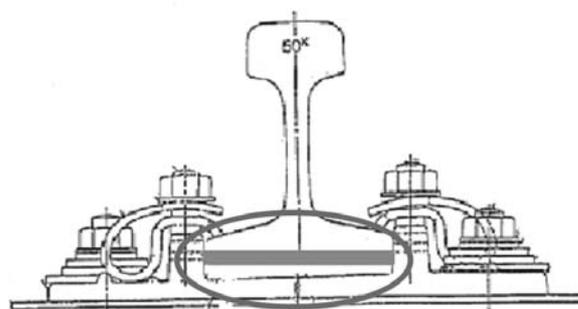


Fig. 20 Cross Section of Track Pad

2.4 Noise Reduction Performance of FASTECH360

Fig. 21 and 22 show the peak levels at the pantograph and the inter-car peak levels without pantographs that were measured using a linear microphone array (time constant 35 ms) at around 387k750 on the Tohoku Shinkansen from August through November 2006, respectively. Fig. 23 shows the measurement results with a nondirectional microphone (dynamic characteristic: SLOW) at around 374k300 and 387k750 on the Tohoku Shinkansen from August through November 2006.

Fig. 21 shows that the pantograph peak level of FASTECH360 with new low-noise pantographs and 30 degree type flat noise insulation plates result in a reduction of more than 2 dB compared to that of the series E2 and more than 5 dB compared to that of the series E3. We also found that the peak level at the folded pantograph is lower than the peak level at the lifted pantograph because the larger part of the folded pantograph is hidden with the noise insulation plates seen from the point of noise measurement.

Fig. 22 shows that the inter-car peak levels of the FASTECH360S and FASTECH 360Z are lower by 1 to 2 dB compared to those of the series E2 and by approx. 4 dB compared to those of the series E3. That is the effect of noise reduction with circumferential diaphragms and sound-absorbing panels at the lower part of the car body. Since Shinkansen trains in the JR East operational area run on slab track, the sound absorption effect at the lower part of the car body is more significant.

As for noise at 25 m, Fig. 23 shows that the improvement of rolling stock explained in 2.3.3 has achieved noise reduction in the

coupled operation of the FASTECH360Z and FASTECH360S by 4 to 5 dB compared to that of the present coupled operation of series E2 and E3. While we could not achieve operation at 360 km/h keeping the noise at the current level, we were able to achieve 330 km/h with the noise level equal to the present coupled operation and 340 km/h for the FASTECH360S train running alone. The reason for the difference is that the FASTECH360Z has a smaller noise reduction effect than the FASTECH360S because the former has to be within the rolling stock gauge of conventional lines.

Comparing Fig. 16 and Fig. 23 clarifies that the structure-borne noise around 374k300 is reduced due to the low-spring constant track pads, better than the noise reduction around 387k750. That means the contribution of structure-borne noise to overall noise cannot be ignored when considering the noise reduction performance of FASTECH360.

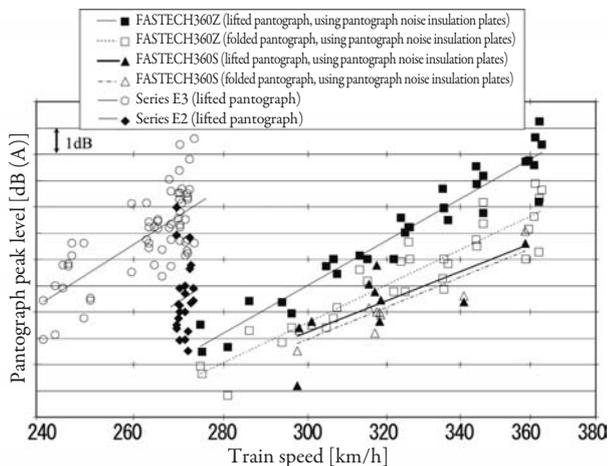


Fig. 21 Pantograph peak level

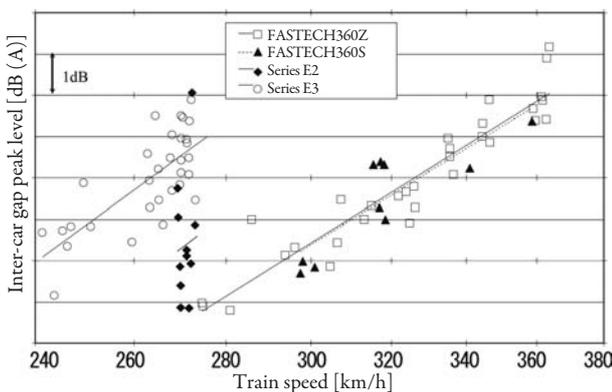
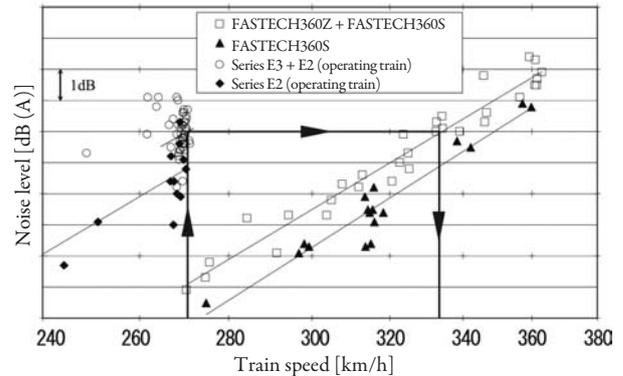


Fig. 22 Inter-car Peak Level

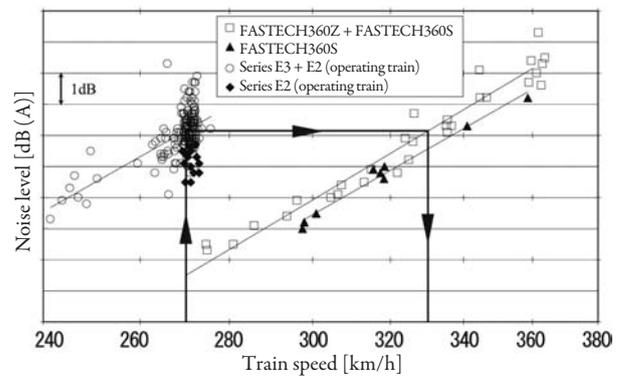
2.5 Contribution of Individual Noise Components to Overall Noise on the FASTECH360S

We estimated the contribution of individual components to overall noise for the FASTECH360S running at 360 km/h in the same way as in section 2.1. The analysis results are shown in Fig. 24. Comparing (a) and (b) of Fig. 24, we found that the overall noise was reduced by more than 4 dB compared to the noise of series E2-1000 trains running at 360 km/h. Furthermore, the

contribution of pantograph noise was reduced by approx. 7 dB and that of the lower part of car body by approx. 1 dB.



(a) Noise at 25 m (around 374k300 on Tohoku Shinkansen)



(b) Noise at 25 m (around 387k750 on Tohoku Shinkansen)

Fig. 23 Noise at 25 m (Measured Aug. - Nov. 2006)

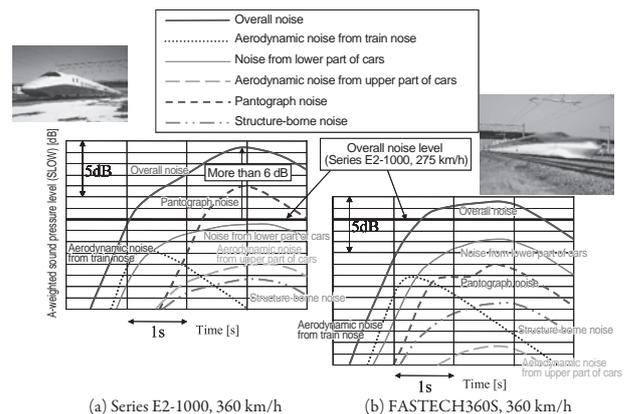


Fig. 24 Contribution of Noise Sources to Overall Noise at 25 m (Series E2-1000 at 360 km/h and FASTECH360S at 360 km/h)

2.6 Current Collection Performance of Pantographs

As explained in section 2.2.1, present Shinkansen trains run with two pantographs per train set. Since the FASTECH360 train set runs only with one pantograph (one pantograph for each train set in coupled operation of the FASTECH360S and FASTECH360Z, Fig. 6), higher current collection performance is required of pantographs. Measurement results of the contact loss ratio of the FASTECH360S (Fig. 25) clarified that both the two types of low-noise pantographs had average contact loss

ratio of 1% or less, which means they have very good current collection performance. While the contact loss ratio increased to 2 - 3% in coupled operation, it is still of a level that would not cause problems. In coupled operation, however, there were cases where the contact loss ratio further increased depending on the intervals between two pantographs used. We thus found that we have to take into account the pantograph interval in coupled operation when designing rolling stock to be used in service.

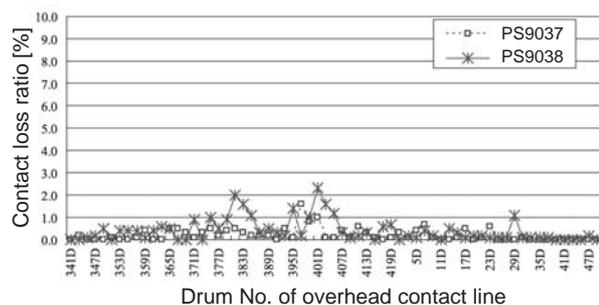


Fig. 25 Contact Loss Ratio of New Low-Noise Pantographs (360 km/h)

2.7 Summary of Chapter 2

- (1) The running speed of coupled operation of the FASTECH360Z and FASTECH360S with the same noise level as present coupled Shinkansen trains (series E3 + E2) is approx. 330 km/h, and it is approx. 340 km/h in FASTECH360S single operation.
- (2) By using new low-noise pantographs and 30 degree type flat noise insulation plates together, the pantograph peak level can be reduced by more than 2 dB compared to that of the series E2 and by more than 5 dB compared to that of the series E3.
- (3) By applying circumferential diaphragms and sound-absorbing panels at the lower part of the car body, the inter-car peak level can be reduced by 1 to 2 dB compared to that of the series E2 and by approx. 4 dB compared to that of the series E3.
- (4) For the contribution of individual noise components to the overall noise of the FASTECH360S running at 360 km/h compared to a series E2-1000 train running at 360 km/h, we presume that the contribution of the pantograph noise is reduced by approx. 7 dB and that of the lower part of the car body by approx. 1 dB.
- (5) Pantograph current collection performance was good for the most part. However, we have to take into account the pantograph interval in the coupled operation when designing rolling stock to be used in service.

3 Reduction of Tunnel Micro-pressure Waves

3.1 Nose Shape

We developed two types of long nose shapes for the FASTECH360S to reduce tunnel micro-pressure waves. That was done by extending the car nose length to 16 m and optimizing the cross section transition through simulations. One shape is a stream-line type nose (Fig. 26(a)), designed from the results of

the cross section transition of the nose optimized to tunnels with a 17 m tunnel entrance hood. Tunnel entrance hoods of this length, the most-commonly installed type for Shinkansen lines in JR East, have openings on the side of the hood optimized for the series E2. The other shape is an arrow-line type nose (Fig. 26(b)), designed according to the cross section transition of the nose optimized to tunnels without tunnel entrance hoods. We produced the FASTECH360S train set with those two types of noses for comparison. The FASTECH360Z, on the other hand, has two types of noses of different length (13 m and 16 m) based on the arrow-line shape. Fig. 27 shows the cross section transitions of the noses of the FASTECH360S and FASTECH360Z and the optimal cross section transitions obtained by simulation. The final shapes of noses for each test train set have lines that are a bit different from the lines of the cross section transition obtained by simulation. That difference is due to the dimensional restrictions of devices such as splitting/combining devices for special high voltage power, snowplows, bogies and cabs. The nose line of the FASTECH360Z that is restricted by the rolling stock gauge of conventional lines differs from the line obtained by simulation, as shown in Fig. 27 (b).

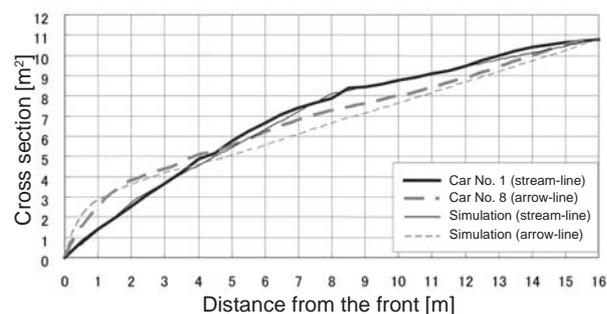


(a) Car No. 1 (stream-line)



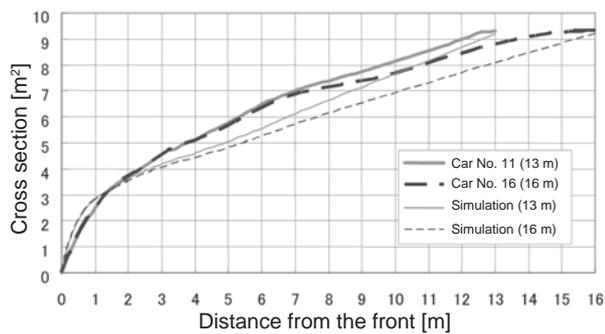
(b) Car No. 8 (arrow-line)

Fig. 26 Nose Shapes of FASTECH360S



(a) Cross Section Transition of FASTECH360S Noses

Fig. 27 Cross Section Transition of FASTECH360S and FASTECH360Z Noses (Final Shapes and Simulation Results)



(b) Cross Section Transition of FASTECH360Z Noses

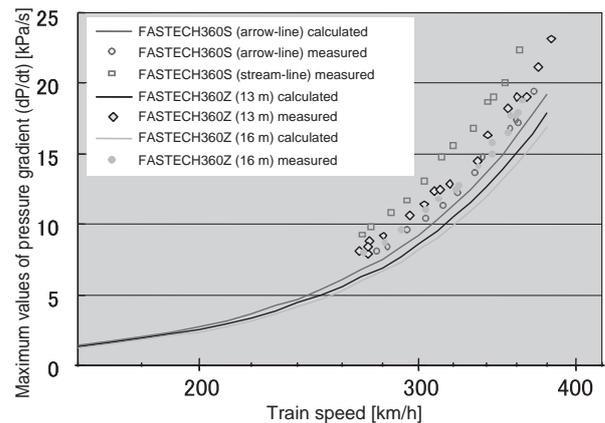
Fig. 27 Cross Section Transition of FASTECH360S and FASTECH360Z Noses (Final Shapes and Simulation Results)

3.2 Running Tests

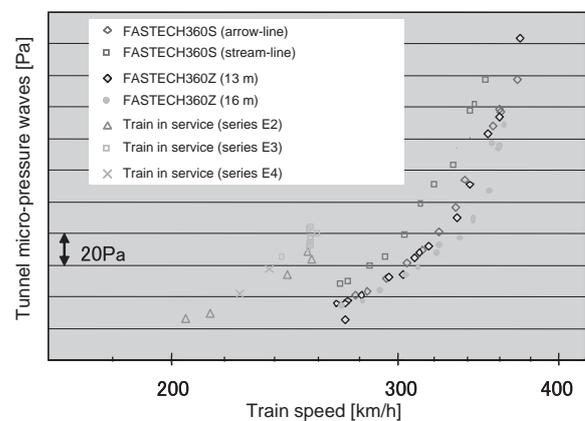
Before the running tests, we installed a new tunnel entrance hood or extended the existing hood at the entrance on the Tokyo side of Dai-ichi-Arikabe Tunnel, Dai-ni-Arikabe Tunnel and Ichinoseki Tunnel to make those hoods have a length of 10 m, 15 m and 25 m respectively. This work enabled us to make measurements on tunnel entrance hoods of lengths 0 m, 10 m, 15 m and 25 m when we included measurements at Omata Tunnel that does not have a hood. In the running tests, we turned around travel directions of the FASTECH360S and FASTECH360Z respectively to compare the tunnel micro-pressure waves for the two types of nose shapes each. The measurement results showed almost the same tendency for tunnel entrance hoods of differing lengths. In this section, we will explain the measurement results for tunnels without hoods and with a 25 m hood as follows.

(1) Without Tunnel Entrance Hood

Fig. 28 shows the measurement results for the maximum values of pressure gradient (smaller values mean smaller tunnel micro-pressure waves) at the tunnel entrance (80 m inside from the entrance) and the measurement results for tunnel micro-pressure waves at 20 m away from the tunnel exit. As shown in Fig. 28, tunnel micro-pressure wave reduction performance of the FASTECH360Z (16m-long nose) was the best. Performance was almost the same for the FASTECH360Z (13 m-long nose) and FASTECH360S (16 m-long arrow-line nose), and that of FASTECH360S (16 m-long stream-line nose) was lower. Comparing the two types of nose shape for the FASTECH360S, we found that tunnel micro-pressure waves generated with the arrow-line shape were smaller than those with the stream-line shape. At the tunnel without a tunnel entrance hood, the difference between arrow-line and stream-line shape performance (difference in speeds of trains entering the tunnel where tunnel micro-pressure waves generated were equal to each other) was 10 - 20 km/h.



(a) Maximum Values of Pressure Gradient at a Tunnel Entrance



(b) Tunnel Micro-Pressure Waves

Fig. 28 Measurement Results (without tunnel entrance hood)

(2) With 25 m-Long Tunnel Entrance Hood

Fig. 29 shows the measurement results for the maximum value of pressure gradient at the entrance of a tunnel with a 25 m-long tunnel entrance hood (80 m inside from the entrance excluding the hood) and the measurement results of tunnel micro-pressure waves at 20 m from the hood exit on the side of the tunnel exit. For these running tests, the openings of the tunnel entrance hood were optimized for the individual nose shapes. As shown in Fig. 29, the maximum values of pressure gradients of the FASTECH360Z with 16 m-long nose, FASTECH360Z with 13 m-long nose and FASTECH360S with 16 m-long arrow-line nose were almost equal to each other when the tunnel entrance hood is 25 m long. Compared to those, the maximum values of pressure gradient of the FASTECH360S with 16 m-long stream-line nose were high. Comparing the two types of nose shape of the FASTECH360S, tunnel micro-pressure waves generated with the arrow-line were smaller than with the stream-line, the same as we found with no tunnel entrance hood. However, the difference in performance between the two nose shapes with a 25 m hood was less than the difference with no hood.

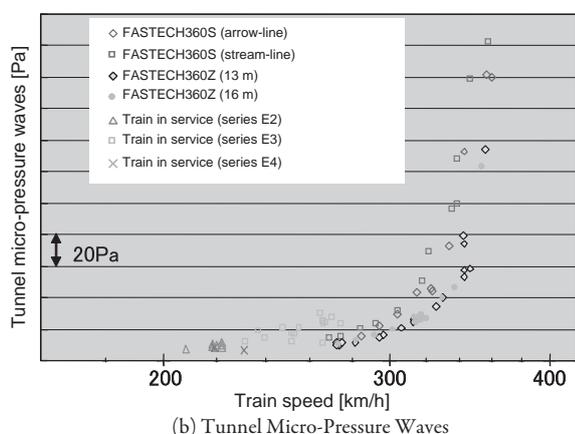
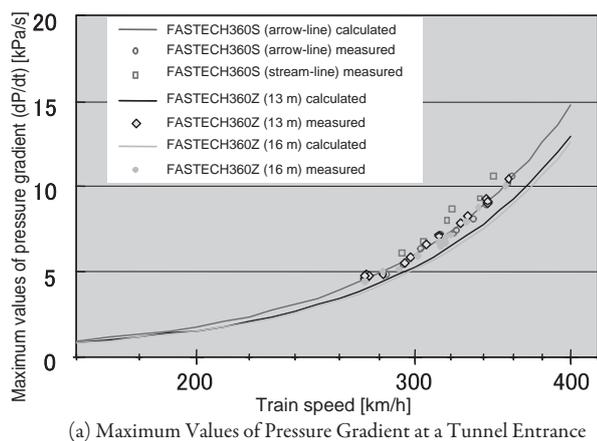


Fig. 29 Measurement Results (with 25 m tunnel entrance hood)

(3) Need to Improve Wayside Equipment

Fig. 30 shows an example of the results of micro-pressure wave measurements for tunnels without tunnel entrance hoods. The figure clarifies that improvement of wayside equipment (installation and extension of tunnel entrance hoods, etc.) is indispensable to increase Shinkansen speed.

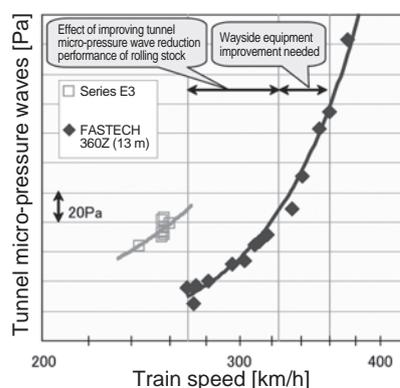


Fig. 30 Example of Measurement Results of Tunnel Micro-pressure Waves (without tunnel entrance hood)

3.3 Summary of Chapter 3

The summary of tunnel micro-pressure wave reduction performance for different car nose shapes is as follows.

- (1) Comparing the two types of nose shape of the FASTECH360S, we found that tunnel micro-pressure waves generated with

the arrow-line shape are smaller than those with the stream-line shape. At the tunnel without a tunnel entrance hood, the difference between arrow-line and stream-line shape performance (difference in speeds of trains entering the tunnel where tunnel micro-pressure waves generated were equal to each other) is 10 - 20 km/h. At the tunnel with a hood, that difference is less than with no hood.

- (2) The FASTECH360S (16 m-long arrow-line nose) and FASTECH360Z (13 m-long nose) are equal to each other in tunnel micro-pressure wave reduction performance.
- (3) Improvement of wayside equipment (installation and extension of tunnel entrance hoods, etc.) is indispensable for increasing Shinkansen speed.

4 Conclusion

The technologies developed using FASTECH360 are used on the new series E5 and E6 with a maximum speed of 320 km/h in commercial operation. Specifically, items such as low-noise pantographs, pantograph noise insulation plates, sound-absorbing panels at the lower part of cars (only on the side skirts) and circumferential diaphragms between cars are applied to the series E5 and E6 for noise reduction. The nose shape of series E5 to reduce tunnel micro-pressure waves is arrow-line of 15 m length, and that for series E6 is arrow-line of 13 m length.

Although the goal of 360 km/h is not yet attained, we confirmed that the technologies developed using FASTECH360 reduced greatly wayside noise and tunnel micro-pressure waves. We will thus continue research and development for further improvement of the environment along Shinkansen lines.

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