Toward Railway Innovation

Ascent

Railway
Technical
Research
Institute

No. 9
October 2021

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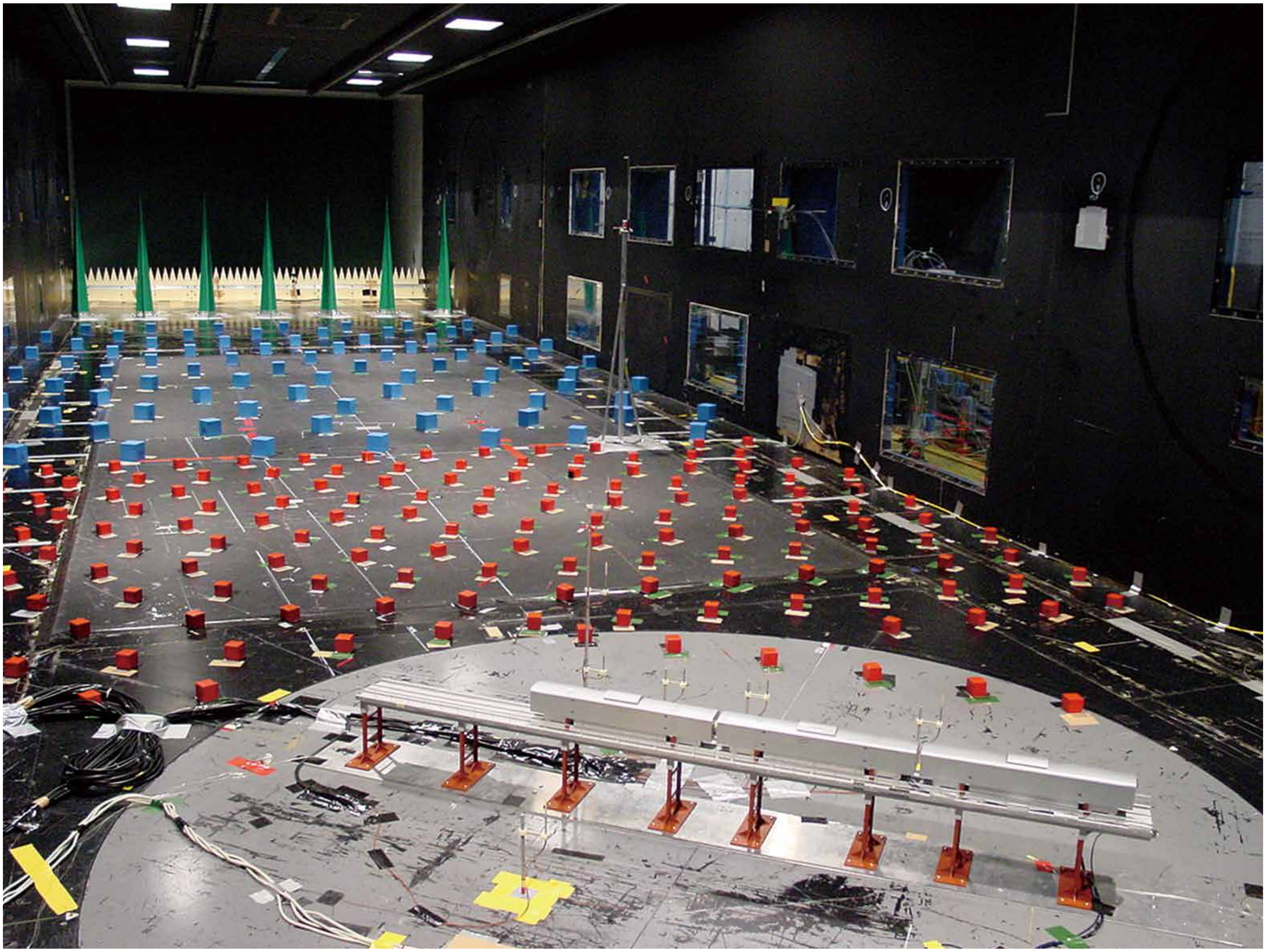
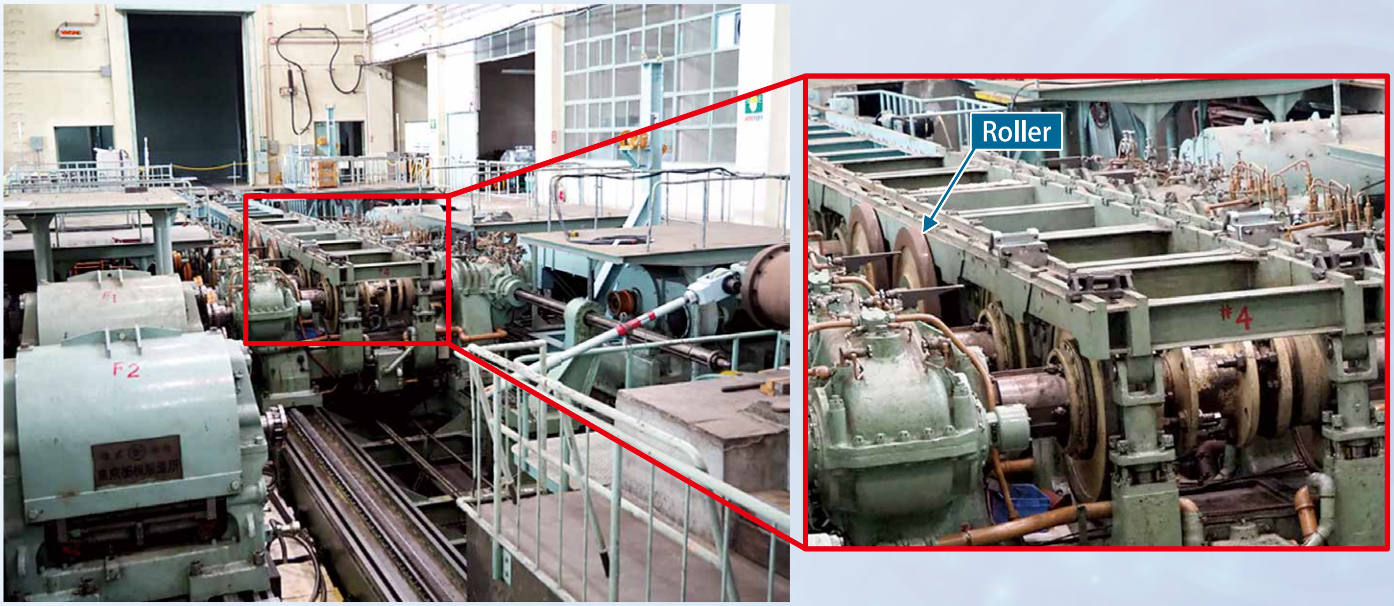
Acoustics and Aerodynamics



RTRI's Rolling Stock Test Plant constructed in 1959 designated as Mechanical Engineering Heritage

On August 7 this year, the Rolling Stock Test Plant at RTRI was designated by the Japan Society of Mechanical Engineers (JSME) as Mechanical Engineering Heritage No. 108 because of its historical value as an existing mechanical engineering asset.



Rolling Stock Test Plant

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Front cover Photo: Wind tunnel tests for the train model on the viaduct under crosswind

Sanyo Shinkansen test vehicle tested on this facility

【Overview of the facility】

- The facility was constructed in 1959 by the predecessor of the current Railway Technical Research Institute (RTRI), which was a research wing of the former Japanese National Railways. Its purpose was to modernize railway traction systems and increase running speeds. Testing was started in 1960.
- High-speed running can be reproduced as a bench test with an actual vehicle. The rail-shaped rollers rotate at high speeds and are capable of simulating train running. The rollers can also add vertical vibration.

(Reference)
Gauge of roller: adjustable between 1000 mm to 1676 mm
Speed: Up to 250 km/h with a vehicle, 350 km/h with a bogie

- It can be used for tests to confirm vehicle performance, including stability at high speeds.
- Test results were used to determine specifications for the test vehicle bogie prior to the opening of Tokaido Shinkansen. The Series 951 test vehicle for Sanyo Shinkansen was also tested at this facility (Sanyo Shinkansen test vehicle tested on this facility) and this facility made a significant contribution to the development of Shinkansen.
- In 1990, RTRI constructed another high-speed vehicle test facility capable of testing at a maximum speed of 500 km/h in order to increase competitiveness of railways over other transport modes. Since then, vehicle running tests have been conducted at the new facility. The historical facility still serves for tests of inverters and other components.

【Note】

In 2007, JSME started to designate objects which are existing in Japan and have historical significance in the development of machine technology and engineering as Mechanical Engineering Heritage. This designation helps to preserve historical items and pass them on to the next generation as cultural heritage. JSME has designated 104 items prior to 2020.

JSME website https://www.jsme.or.jp/kikaiisan/#section1

Dr. Tetsuo Uzuka
Managing Editor
(General Director,
International Division)

Preface Message from the General Director Dr. Tetsuo UZUKA

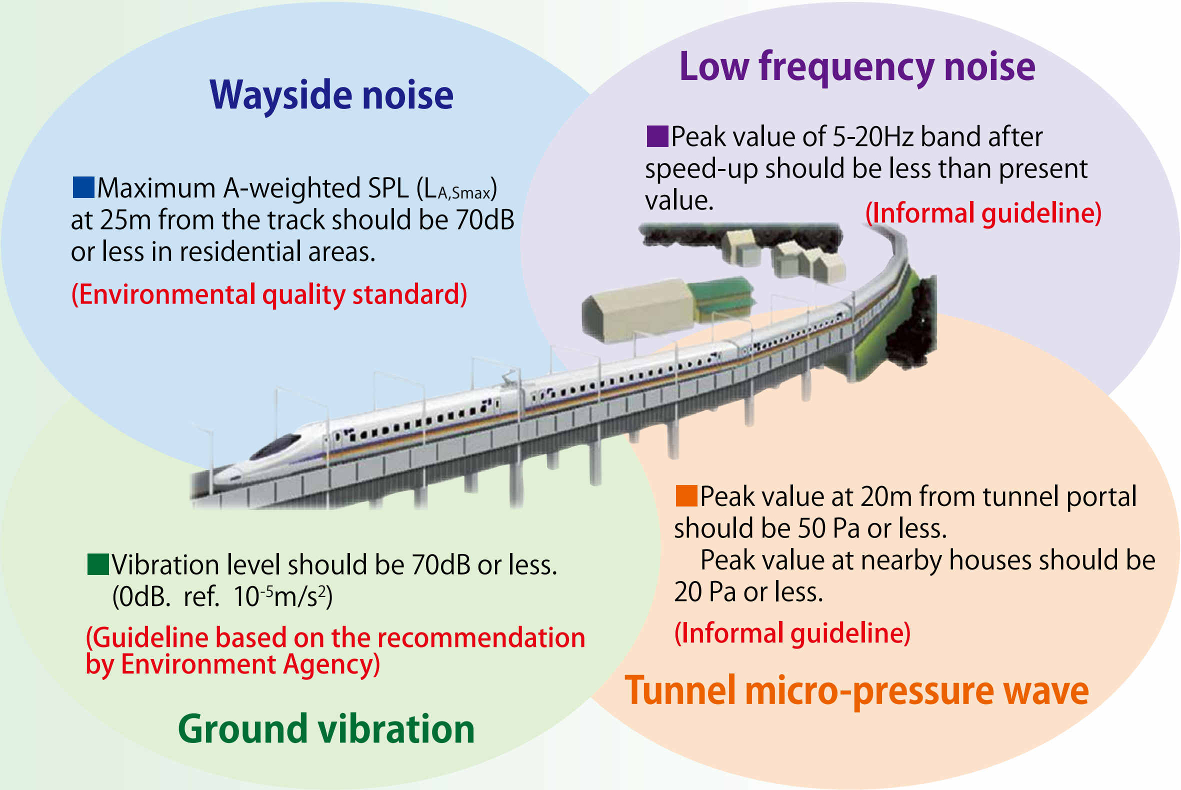
The establishment of Shinkansen HSR in 1964 was one of the biggest landmarks for railways, but it also invoked environmental problems such as noise and vibration along the railway. Since the days of the Japanese National Railways (JNR), RTRI has been working to address these environmental issues, and has contributed to the continuing operation of high-speed trains.

In 2021, the world's environmental problem is global warming, and railways are becoming increasingly important. By reading the following articles you will find out how the environmental solutions of the 20th century are also helping to solve problems in the 21st century.

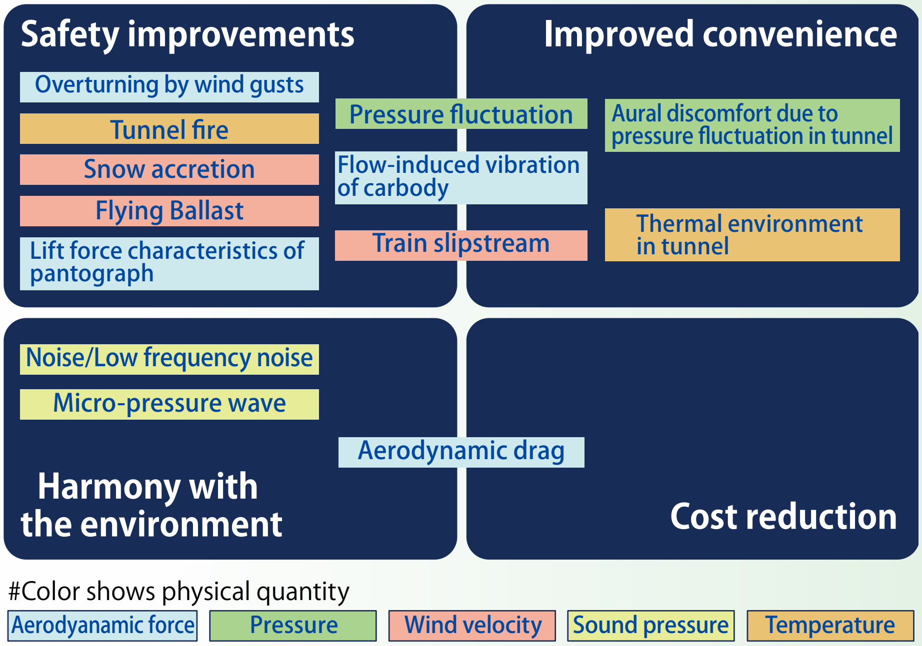
Environmental Engineering Division of the Railway Technical Research Institute

The Environmental Engineering Division, which consists of the three laboratories of Vehicle Aerodynamics, Heat and Air Flow Analysis, and Noise Analysis, conducts R&D on the wayside environment and aerodynamic phenomena. The following outlines the issues related to the wayside environment and aerodynamic phenomena and introduces the recent R&D status of RTRI related to the speeding up of the Shinkansen, which is closely related to both.

Dr. Kiyoshi Nagakura
Director
Environmental Engineering Division



Wayside environmental issues in high-speed railways



Aerodynamic issues in railways

Wayside environmental issues in railways

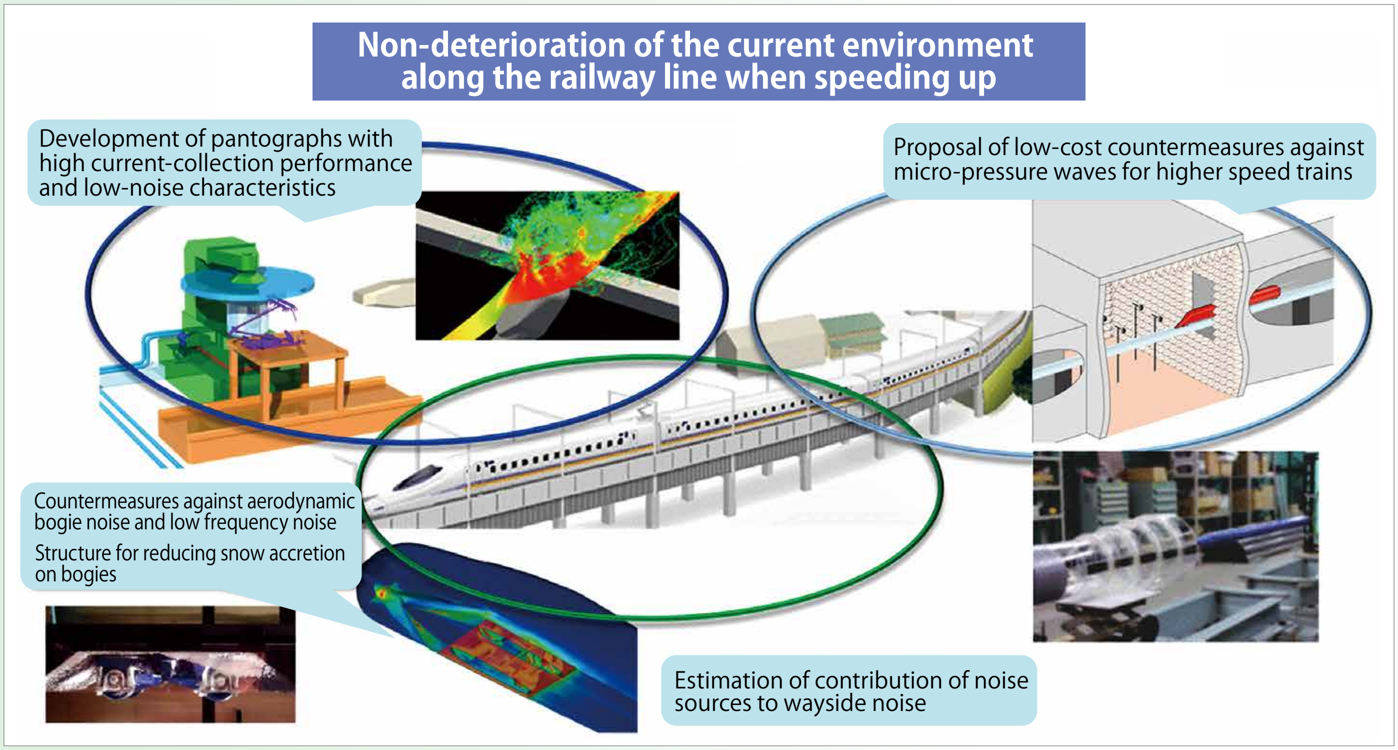
The railway offers high energy efficiency as a means of transportation, which is beneficial to the global environment, in particular for decarbonization. On the other hand, passing trains can be the cause of a range of wayside environmental issues such as acoustic noise, low-frequency sound, micro-pressure waves, and ground vibration (Wayside environmental issues in high-speed railways). Since these phenomena have a large effect on the wayside environment on routes with a large wayside population such as the Shinkansen in Japan, train operation of the Shinkansen requires that the standard values and guideline values related to these phenomena be observed. The effects of these physical phenomena increase rapidly with increasing speed; therefore, it is essential to develop technology to mitigate the environmental load in order to achieve both “the improvement of convenience by improving the vehicle speed and transport capacity” and “the maintenance and improvement of the wayside environment.” RTRI is continuously conducting R&D on phenomenon elucidation and the prediction, evaluation, and reduction methods for these problems.

Aerodynamic issues in railways

As trains run through the air, the resultant interaction between the vehicles and surrounding air produces aerodynamic force acting on the vehicles and aerodynamic phenomena occurring along the wayside. More specifically, possible effects on vehicles include overturning by wind gusts, aerodynamic drag, flow-induced vibration of car body and aerodynamic lift force on pantographs. Possible phenomena along the wayside include aerodynamic noise, micro-pressure waves from tunnel exits, low frequency noise caused by passing trains, flying ballast, accretion of ice and snow, train slipstream, and other phenomena acting on wayside structures and people. In tunnel sections, phenomena such as atmospheric pressure fluctuations in the tunnel, temperature changes, and smoke flow during a fire are also added. Aerodynamic issues in railways summarizes the aerodynamic phenomena that pose issues in railways. As shown in the figure, these phenomena are related to many matters concerning the basic characteristics of railways, such as safety, convenience and comfort, harmony with the environment, and cost reduction; RTRI is continuously conducting R&D to solve issues related to these phenomena.

Efforts to improve the Shinkansen vehicle speed

Needless to say, shortening the time to arrival by increasing speed is one of the most effective measures to improve the value of railways, however, there are many issues in terms of safety, comfort, and environmental compatibility for increasing the Shinkansen vehicle speed. RTRI’s mid-term master plan “RESEARCH 2025 –



Increasing Shinkansen train running speeds in harmony with the trackside environment

Research and Development for Creating the Future of Railways –" identified (1) issues with wayside noise and low-frequency sound and tunnel micro-pressure waves as those affecting the wayside environment and (2) issues with snow accretion on railway bogies as those related to safety and stability in harsh environmental conditions such as extremely cold and heavy snowfall areas. We are tackling these issues by setting a future-oriented plan, "Increasing Shinkansen train running speeds in harmony with the trackside environment" (Increasing Shinkansen train running speeds in harmony with the trackside environment).

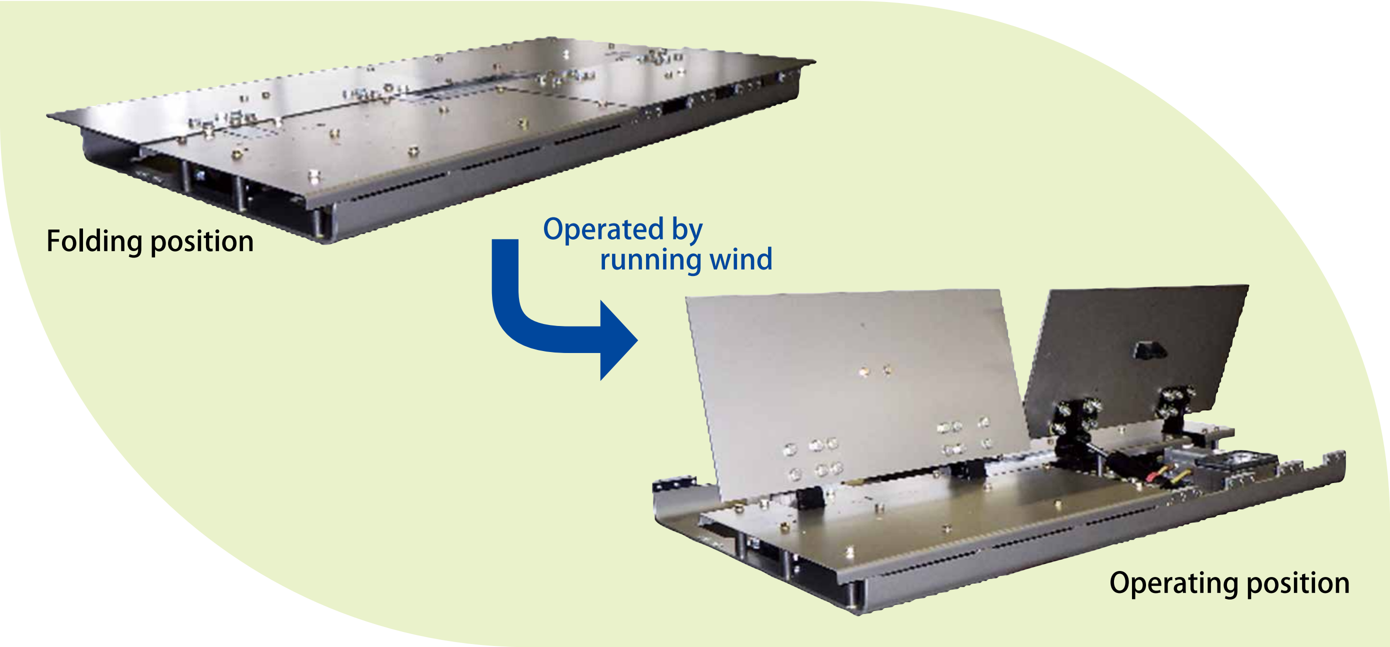
We will utilize the test methods and numerical simulation methods that we have developed so far to promote this R&D. In particular, large-scale test equipment such as the large-scale low-noise wind tunnel, will be used. The Low-Noise Moving Model Test Facility, completed in FY2020, and the High-Speed Test Facility for Pantograph/OCL Systems (HiPaC) are unique to RTRI, and we believe that these will play a major role in promoting the research. As research products, we plan to obtain:

- the low-cost tunnel micro-pressure wave countermeasures,
- the bogie structure that reduces aerodynamic noise and low frequency noise and suppresses snow accretion,
- a pantograph that has both current collection performance and low noise,
- the sound source contribution analysis and evaluation methods for wayside noise,
- a risk assessment method for accreted and falling snow.

We plan to verify the effects of some of these through field tests in collaboration with railway operators.

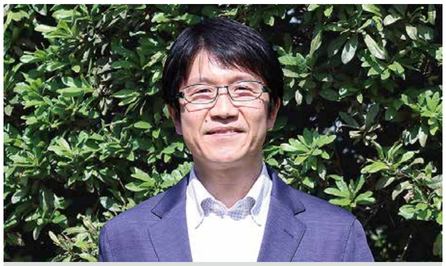
Conclusion

Many of the effects of wayside environmental or aerodynamic phenomena intensify significantly as the running speed increases; therefore, this R&D is thought to become increasingly important for future increases in railway speed. To solve the issues, highly accurate current vehicle test data is indispensable in addition to utilizing advanced experimental and numerical analysis methods. Any proposed measure must be evaluated in various respects including ease of construction, cost and the possibility of inducing other physical phenomena before being put in place. We will continue to hold discussions with railway operators to elucidate phenomena and put countermeasure technologies into practical use.



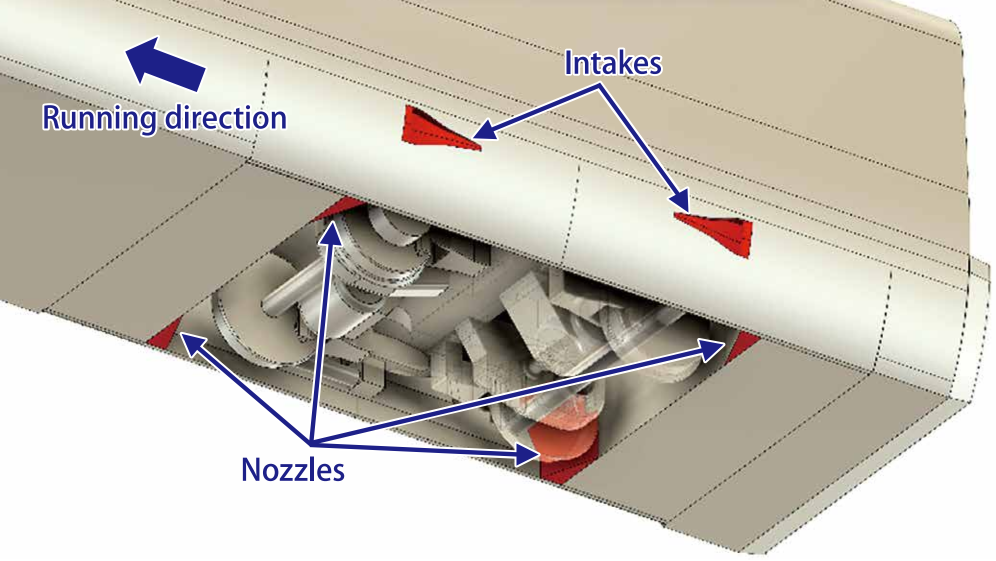
Aerodynamic brake device

Vehicle Aerodynamics Laboratory



Mr. Minoru Suzuki
Laboratory Head
Vehicle Aerodynamics

The Vehicle Aerodynamics Laboratory deals with various railway-related aerodynamic phenomena found mainly in open sections. The main research topics we are currently working on include issues targeting the flow field around high-speed vehicles such as the Shinkansen (e.g., aerodynamic brake device for Shinkansen speed improvement, measures to prevent snow accretion on the bogie section using the running wind, high-speed train roof flow analysis for understanding the performance of the current collector) and issues related to safety evaluation against the natural wind (e.g., evaluation of the aerodynamic characteristics of vehicles under cross winds, evaluation of the wind load acting on objects lying on the track surface). This paper introduces three research examples out of these.



Intake and nozzle layout

Aerodynamic brake device for Shinkansen speed improvement

The aerodynamic brake device is a non-adhesive system that temporarily increases the air resistance acting on a running train to directly decelerate the vehicle. It complements the conventional braking force mainly in the high-speed range when sudden deceleration is required in an emergency such as an earthquake.

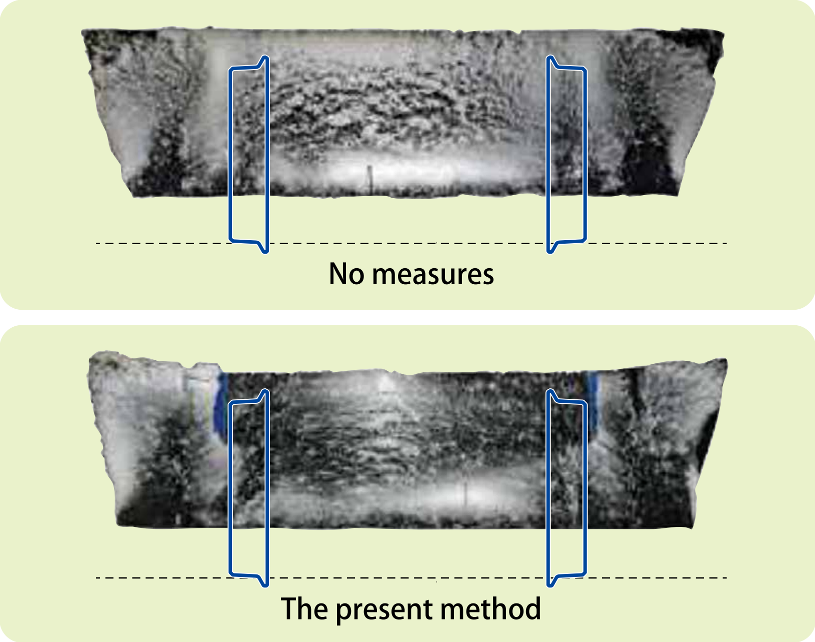
Its feature is that it can decelerate directly by using the air resistance of the vehicle without relying on the wheels or rails. Higher vehicle speeds provide higher deceleration because air resistance generally increases in proportion to the square of the train speed. A mechanism is incorporated that uses headwind to cause the resistance panel to stand on its own, thereby realizing a compact and lightweight configuration with a device thickness of 65 mm and a mass of 36 kg. This allows it to be stored compactly during normal operation without affecting passenger space. It has been verified to have no safety issues by conducting a vibration test, low temperature freezing test, bird striking test, computational fluid dynamics (CFD) analysis, etc., in addition to a 400 km/h wind tunnel test.

It is expected to be used to shorten the emergency stop distance when the Shinkansen vehicle speed is increased in the future.

Measures to prevent snow accretion on the bogie section using passing air

Countermeasures against snow have been an issue in the recently promoted extension of Shinkansen to snowy areas such as Hokkaido and Hokuriku. Thus, we have developed a method to control the flow of snow particles around bogies and prevent snow accretion mainly on body panels behind the bogie. This will improve safety against snow falling from vehicles and reduce accreted snow removal work in snowy areas. The method consists of an intake that takes in the air passing the side of each bogie and a nozzle that blows out this air to the bogie (Intake and nozzle layout).

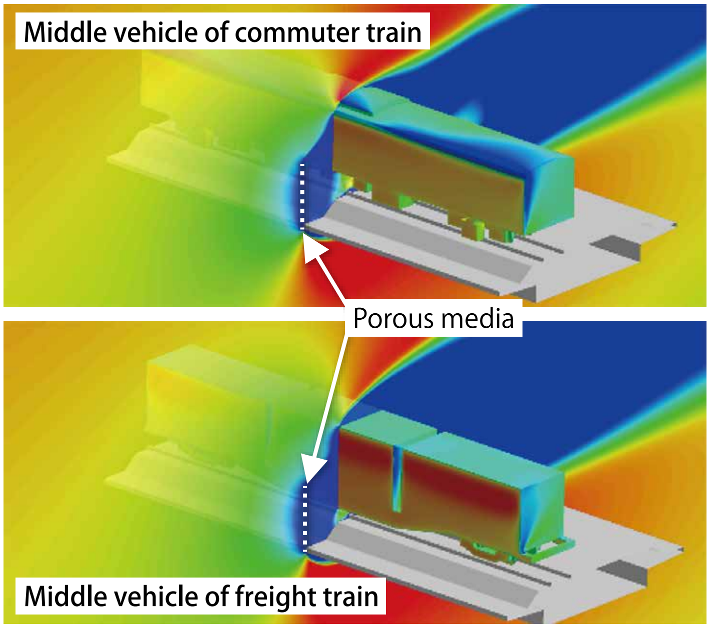
We conducted an experimental model running test and a snow wind tunnel test to reproduce the snow particle advection and snow accretion into the bogie. The results showed a potential reduction in snow accretion mass at the body panel of approximately 50% (Verification of the effect of reducing the snow accretion mass). In addition, as a result of simulating a shape that was expected to have a snow accretion suppression effect through a model experiment, we have verified that the number of accreted snow particles on the body panel was reduced by approximately 30%. We also investigated the effect of the intake shape on aerodynamic noise in a large-scale low-noise wind tunnel and verified that the increase in noise level due to the addition


No measures

The present method

Verification of the effect of reducing the snow accretion mass of snow accretion measures can be suppressed to less than 1 dB.

In the future, we will apply this method to actual Shinkansen vehicles to verify the effects of snow accretion prevention and noise increase.



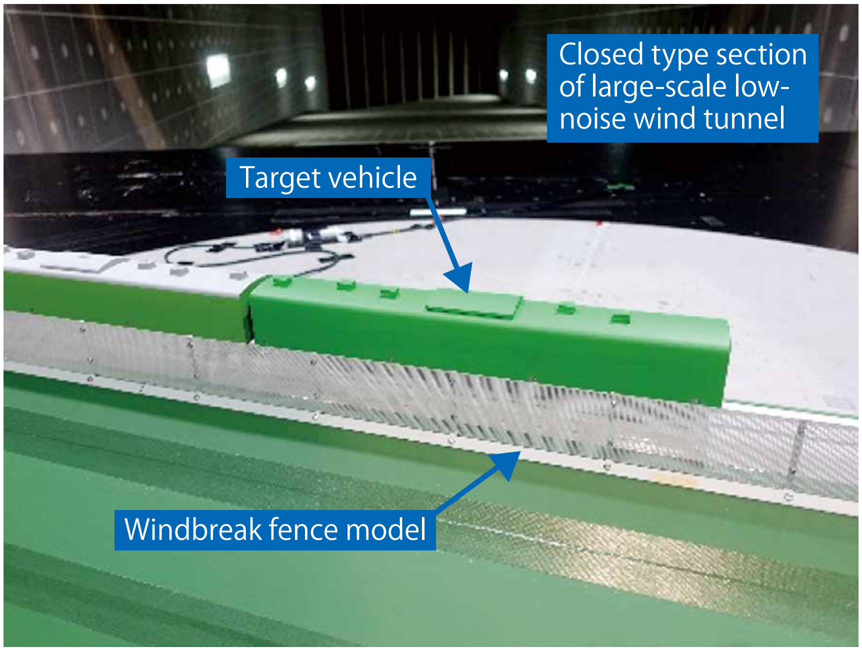
CFD analysis that reproduced the wind tunnel test for the windbreak fence

Evaluating aerodynamic characteristics of vehicles under cross wind

RTRI conducted wind tunnel tests with five types of typical vehicles and seven types of track structures in the previous studies, and summarizes the aerodynamic coefficients of the five vehicles under cross winds. These coefficients have been used to evaluate vehicle running safety in strong winds and review train operation control methods. However, the coefficients of aerodynamic force for the condition with a windbreak fence have not been comprehensively obtained, and it was sometimes difficult to evaluate the critical wind speed of overturning if countermeasures against strong winds were taken.

Thus, we conducted a wind tunnel test to measure the aerodynamic forces with a windbreak fence (Wind tunnel test for the windbreak fence) to expand the data of aerodynamic force coefficients and clarify the improvement in the critical wind speed of overturning by installing the windbreak fence. We also developed a method of CFD analysis that can consider the effect of the windbreak fence, and conducted CFD analysis to reproduce the wind tunnel tests using the windbreak fence model (CFD analysis that reproduced the wind tunnel test for the windbreak fence). By comparing with the results of the wind tunnel test, we have verified that the effects of vehicle shapes and track structures on the amount of aerodynamic force reduction caused by the windbreak fence are properly reproduced in CFD analysis.

For vehicles with the same roof curvature radius, we have clarified the differences in aerodynamic force coefficients obtained from the wind tunnel test and CFD analysis, and also revealed the differences in critical wind speed of overturning calculated from the aerodynamic force coefficients.



Wind tunnel test for the windbreak fence

Heat and Air Flow Analysis Laboratory

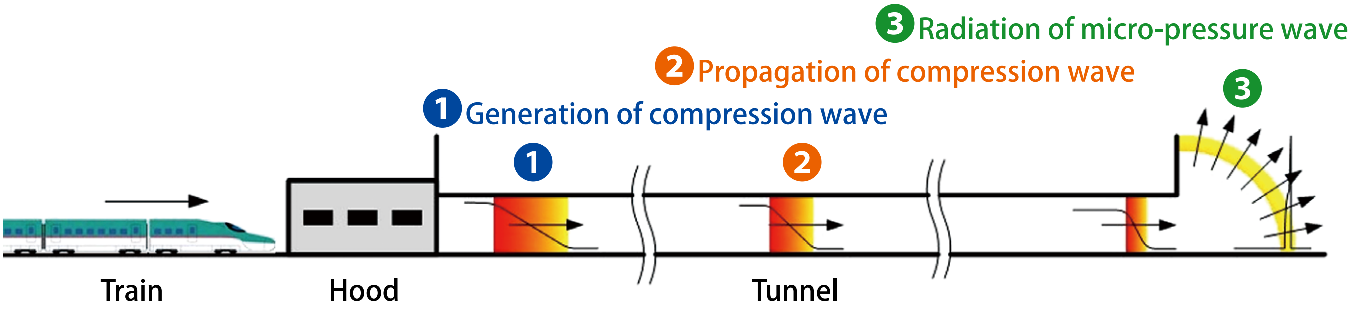
Dr. Sanetoshi Saito
Laboratory Head
Heat & Air Flow Analysis

The Heat and Air Flow Analysis Laboratory deals with various aerodynamic phenomena in a tunnel. Our current main research subjects include those related to compressible fluids (e.g., micro-pressure waves radiated from the tunnel exit to the outside when the train enters the tunnel, and train draft and pressure fluctuation in the tunnel) and those related to heat and fluids (e.g., temperature rise in the tunnel due to train running, and understanding the flow behavior of hot gas in a tunnel fire). The following introduces research activities concerning micro-pressure waves and hot gas flow in tunnel fires.

Micro-pressure wave

When a train enters a tunnel at high speed, a compression wave is generated in the tunnel. This wave propagates through the tunnel at the speed of sound, resulting in a radiation of pulsed pressure waves from the other portal of the tunnel (Generating mechanism of micro-pressure waves). These pressure waves, called micro-pressure waves, generate blasting noise and shake houses near tunnel portals; therefore, we should take measures to reduce them.

The magnitude of micro-pressure wave is proportional to the maximum value of the pressure gradient of the compression wave in the tunnel (time derivative of pressure). Therefore, the basic principle for the measures is to reduce the maximum pressure gradient of the compression



Generating mechanism of micro-pressure waves

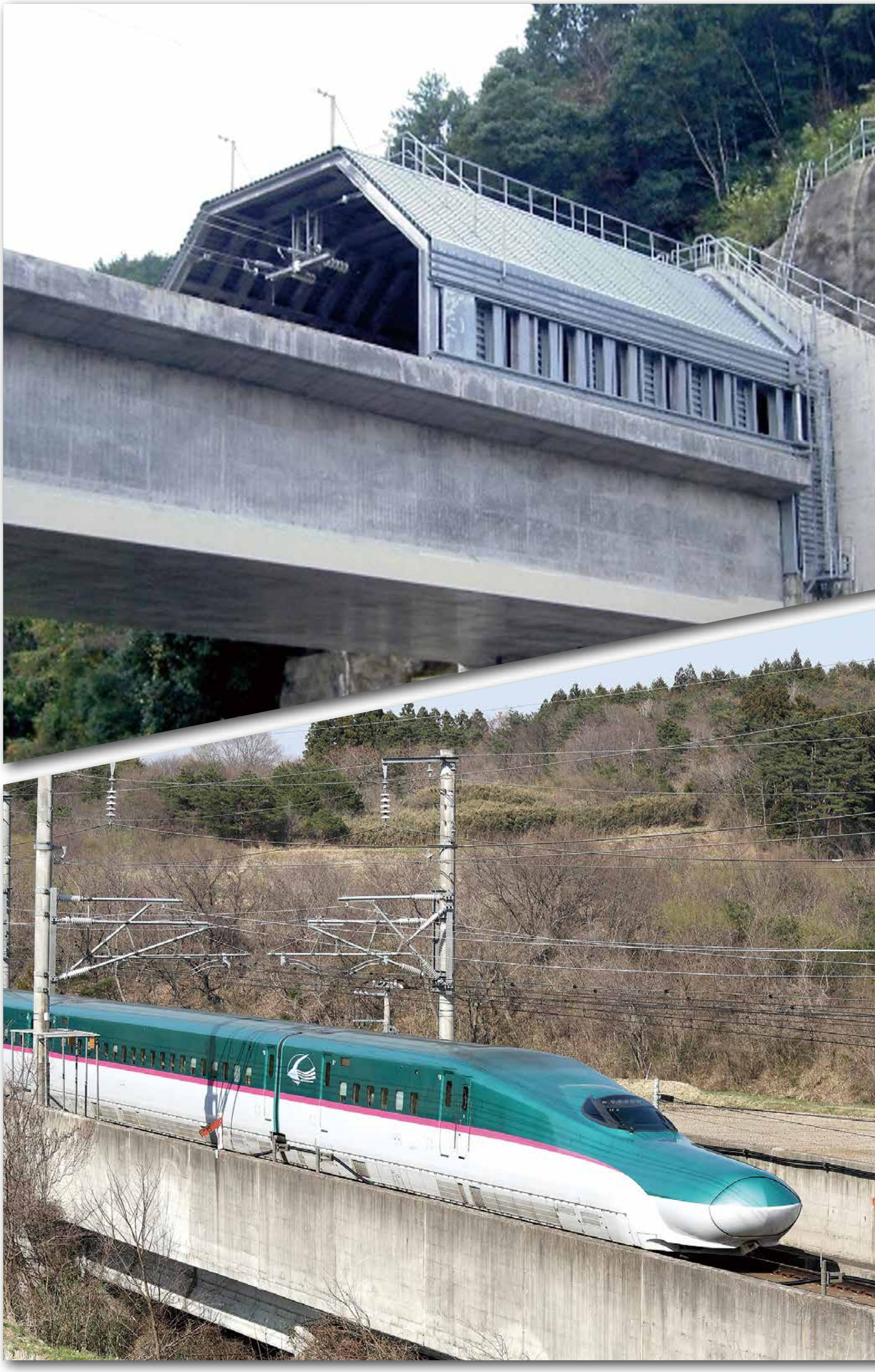
wave in the tunnel, that is to lengthen the formation time of the compression wave. The main measures implemented under this principle include a hood installed at the tunnel entrance (Tunnel entrance hood), and a train nose lengthened and optimized (Lengthened and optimized train nose).

The tunnel entrance hood is the most important measure to reduce the micro-pressure wave. However, the construction cost can be very high because the total length is required to be several tens of meters or more for vehicle speeds of 300 km/h or more. As such, we are currently researching ways to shorten the length of the entrance hood to reduce the cost. Model experiment of two-step entrance hood shows an example of the achievements, which is a two-step entrance hood with a larger cross-sectional area at its forefront than the conventional one. We determined the optimal cross-sectional area and length of the forefront by numerical calculation and model experiment and verified that it has the same performance as the conventional hood with a shorter length than the conventional one.

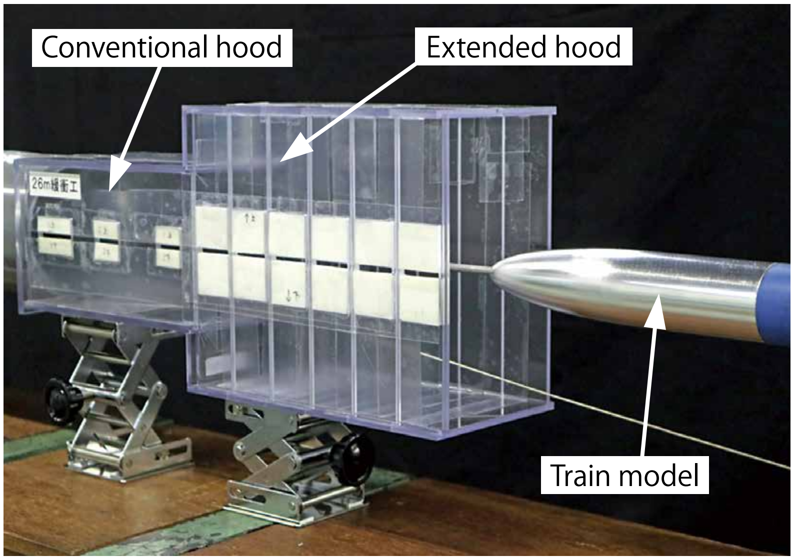
Tunnel fire

Although there are few cases of fires in railway tunnels, they can be hazardous situations because railway tunnels are very narrow and easily filled with smoke. Furthermore, unlike road and subway (urban) tunnels, railway mountain tunnels are not equipped with ventilation for smoke exhaust, making it difficult to predict the flow of smoke. Thus, we are studying smoke flow (i.e., hot airflow) prediction by numerical simulation.

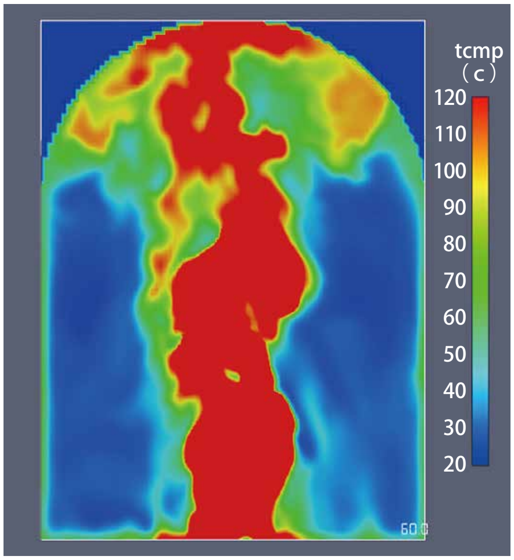
When a fire occurs in a tunnel, the hot gas impinges on the ceiling due to its buoyancy, then travels toward the tunnel



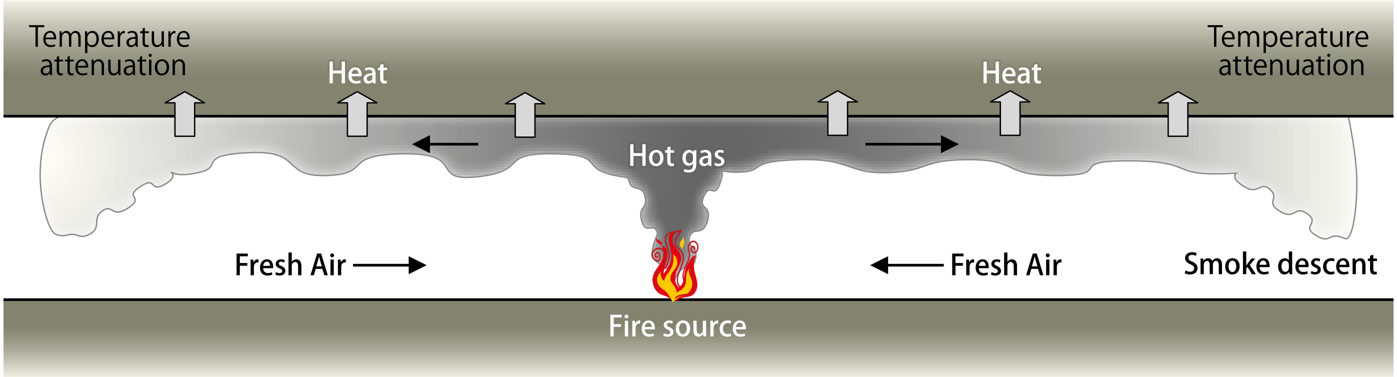
Upper row: Tunnel entrance hood
Lower row: Lengthened and optimized train nose



Model experiment of two-step entrance hood



Example of simulation of hot gas



Schematic diagram of hot gas in a tunnel fire

portals beneath the ceiling, and fresh air flows under it from the portals entrance toward the fire source (Schematic diagram of hot gas in a tunnel fire). The hot gas traveling beneath the ceiling is cooled by the ceiling wall and the fresh air flowing under the hot gas, and it gradually descends to the ground due to the decrease in its buoyancy. The numerical simulation, therefore, requires that not only flow field but also the heat transfer be accurately solved, making it difficult to assure calculation accuracy. Thus, we have also conducted model experiments and have verified the validity of the calculation model by comparing the experimental results with the calculation results. As an example, Example of simulation of hot gas shows a result of calculating the temperature distribution near the fire source installed on the tunnel floor.

The above is an introduction of research activities that the Heat and Air Flow Analysis Laboratory has conducted recently. We will continue to research the aerodynamic phenomena in a tunnel through theoretical analysis, numerical analysis, model experiments, and other means.

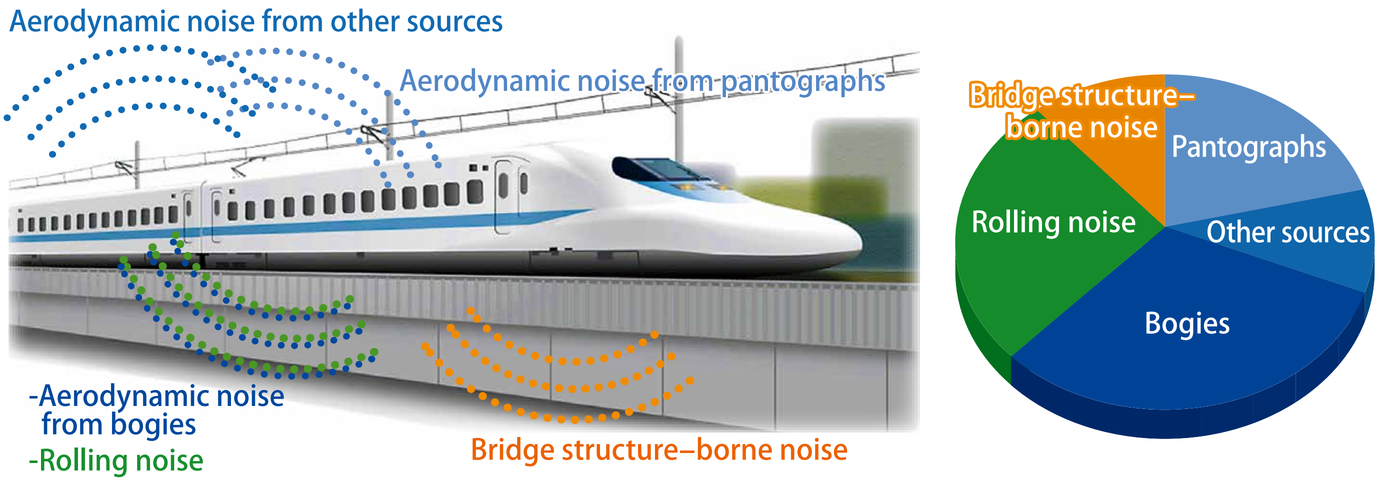
Ms. Yukie Ogata
Laboratory Head
Noise Analysis

Noise Analysis Laboratory

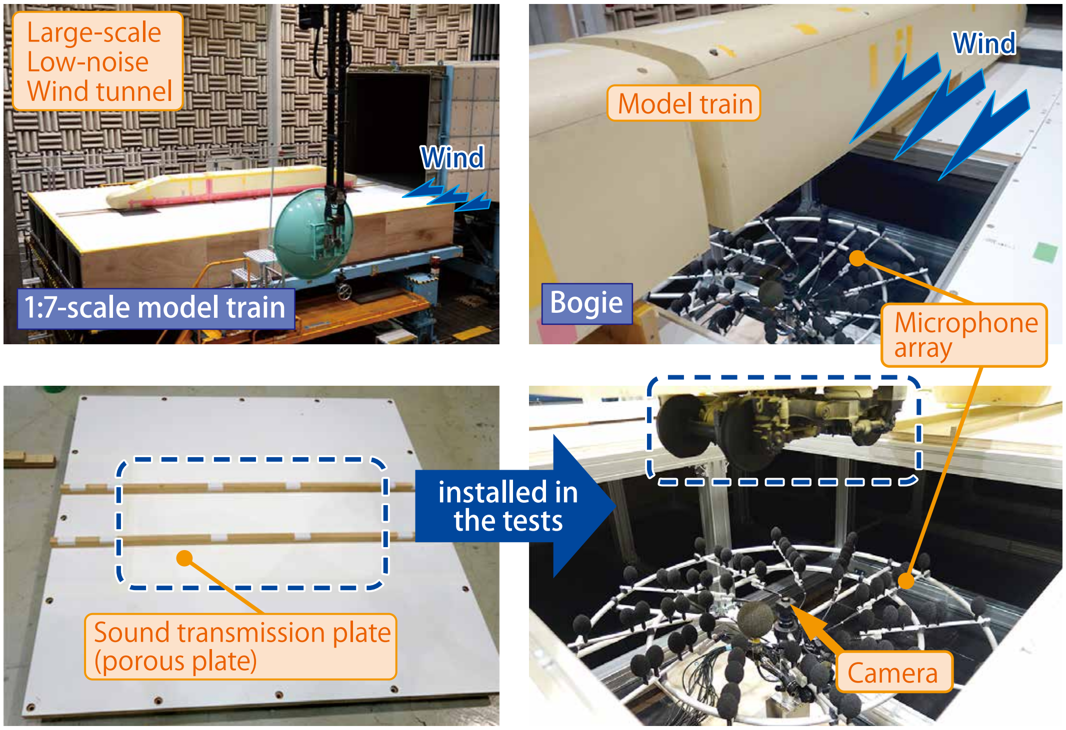
Targeting the conventional lines, Shinkansen lines and maglev, the Noise Analysis Laboratory is researching noise source analysis and reduction measures for railway noises. Examples of noise sources are aerodynamic noises generated by the vehicle running at high speed, and structure-borne noises caused by the vibration of wheels, rails, and railway structures. The Noise Analysis Laboratory is also expanding the capabilities of the noise prediction model, focusing on the effects of wayside structures on noise propagation. The following gives more details with a focus on the Shinkansen.

Source analysis of Shinkansen noises

Railway noise is complex and composed of various noise sources with different generation principles. To reduce such complex noise effectively, we need to examine the contributions of respective noise sources in the wayside and take measures against noise sources with large contributions, with priority given to these. Wayside noises of the Shinkansen lines are classified into pantograph noises, upper part aerodynamic noises, lower part noises (rolling and aerodynamic noises), and bridge noises according to the location of noise generation (Noise sources of Shinkansen and contribution of each noise source at a point 25 m away from the track). The results of noise source analysis using data from our field test showed that when the latest-model Shinkansen vehicles run at a speed over 300 km/h, the contribution of noises from the vehicle's lower part is



Noise sources of Shinkansen and contribution of each noise source at a point 25 m away from the track
(Concrete viaduct, slab track, noise barrier with a height of 2 m and train speed at 320 km/h)



Evaluation of aerodynamic noise from the carbody

Microphone array was located beneath the bogie, and sound source detection was conducted by using sound transmission plate.

the largest, followed by that of pantograph noise. The aerodynamic noise from the lower part of the vehicle was found to increase with running speed (Noise sources of Shinkansen and contribution of each noise source at a point 25 m away from the track).

Aerodynamic noise

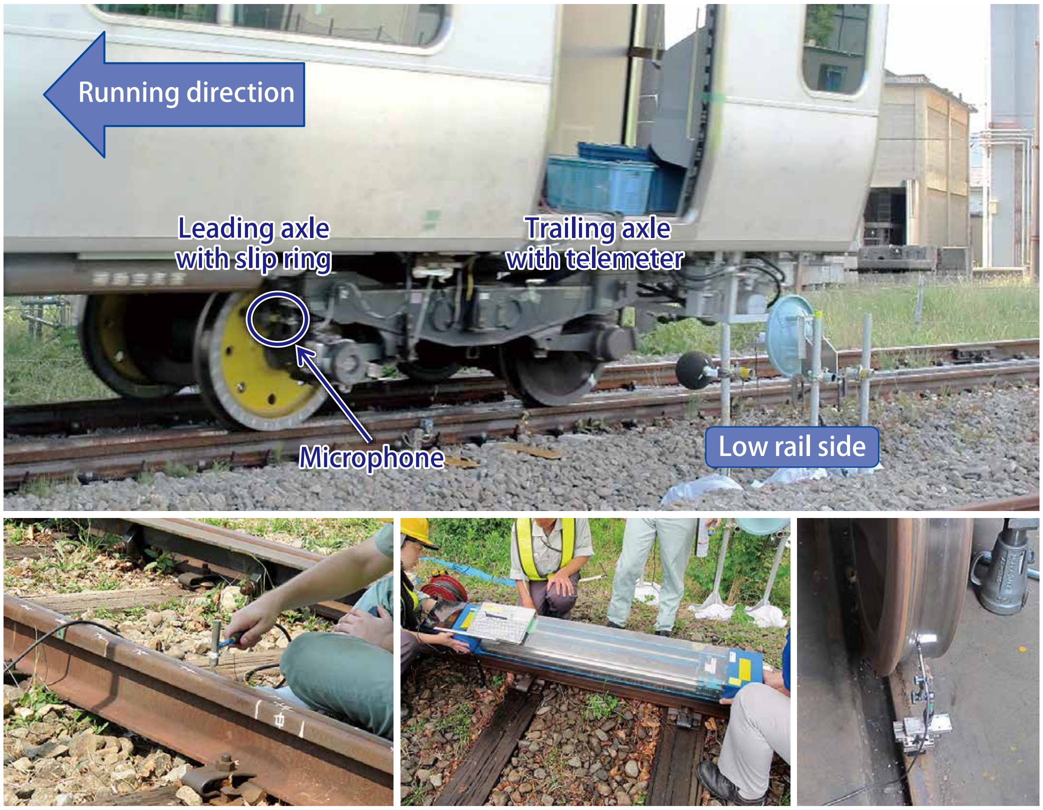
To suppress the increase in wayside noises of the Shinkansen due to its running speed increase, we need to elucidate the generating mechanisms of aerodynamic noises from the bogie section and the current collection system and develop measures to reduce them. Thus, regarding aerodynamic noises in the bogie section, we used wind tunnel testing to study the benefits of using a noise transmission plate (Evaluation of aerodynamic noise from the carbody). From the results, we confirmed that there are main noise sources near the traction motor and gear unit and that noises can be reduced by attaching a member that controls air flow to the bogie. Recently, based on the results of a field test using a 2-dimensional array device with many microphones placed in one plane, we studied the development of a method for evaluating the noise source distribution around the vehicle and the measures to reduce noise in the low-frequency range of 100 Hz or lower.

Structure-borne noises

Regarding structure -borne noises such as rolling noise and bridge noise, we conducted various measurements to elucidate the generating mechanisms of tread squeal noise when a vehicle passes through a curve and the impact noise generated when it passes over rail joints. These included simultaneous measurement of on-board noises and noises on the ground, surface roughness measurements of rail and wheel tread, and rail vibration tests (Structure-borne noise measure technique). We are constructing a physical model based on these experimental results. We are also studying a method for evaluating the effect of irregularity on the wheel tread of the Shinkansen vehicle on wayside noises.

Noise propagation

Regarding noise propagation, we work to extend the capabilities of the prediction

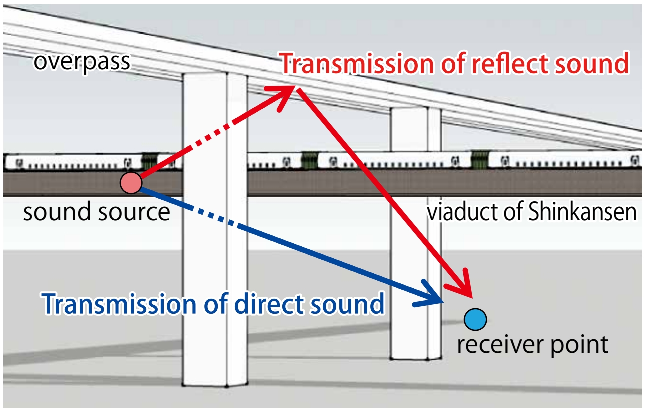


Structure-borne noise measure technique

method for the wayside noise. For example, we evaluated the noise distribution from acoustic scale model experiments and field tests for peripheral areas of cut sections, tunnel portals, and overbridges, and constructed a prediction model based on these results (Transmission model of wayside noise considering the reflect sound on the bottom of the overpass). We are also studying the conditions where multiple factors affect noise propagation (e.g., area where an overpass and buildings of wayside are combined, densely populated residential area).

Conclusion

We have conducted several field tests, acoustic scale model experiments, and simulations to construct a method for predicting wayside noises and evaluating the noise abatement effect of countermeasures. A deep understanding of the phenomena involved in the generation and propagation of railway noise is essential for the goal of reducing wayside noise; we will continue to make efforts in the future.



Transmission model of wayside noise considering the reflect sound on the bottom of the overpass

RTRI Large-Scale Low-Noise Wind Tunnel

Dr. Atsushi Ido
Director
Wind Tunnel Technical Center

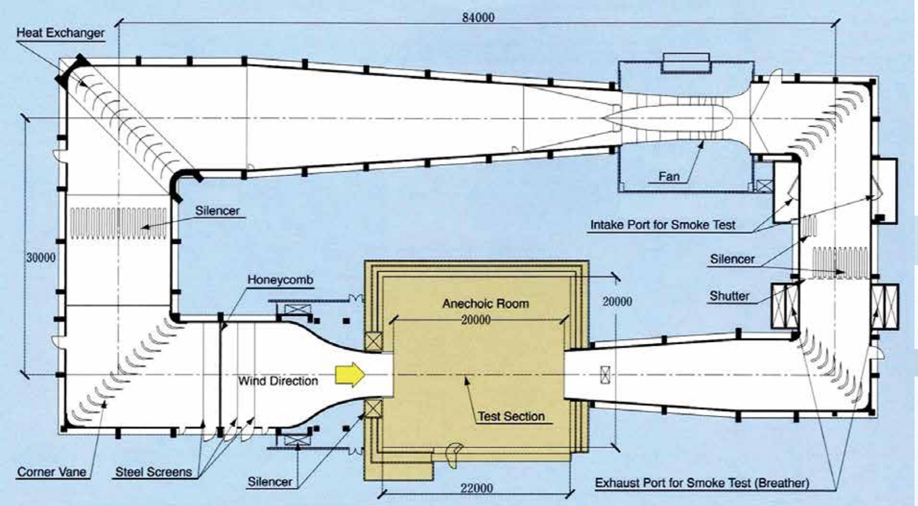
RTRI built a large-scale, low-noise wind tunnel (hereinafter “Maibara Wind Tunnel”) in Maibara City, Shiga Prefecture in 1996 for the R&D of railway aerodynamic issues, including aerodynamic noise. At the Maibara Wind Tunnel, we have contributed to various R&D activities related to aerodynamics by conducting more than 200 days of tests every year from opening the facility to the present. In particular, "safety" and "environment" are the most important issues in railways. Therefore, we have been actively researching and developing vehicle running safety in cross winds and aerodynamic noise reduction. This article overviews the characteristics of the Maibara Wind Tunnel built for the railways, a tunnel which has low background noise (noise generated by the wind tunnel during air blowing), a long test section, and to simulate air flow near the ground. It also summarizes the cross wind and aerodynamic noise-related R&D that utilizes the Maibara Wind Tunnel.

Wind Tunnel Test Facilities

General arrangement shows a plan view of Maibara Wind Tunnel. Table summarizes its main specifications.

Test Sections

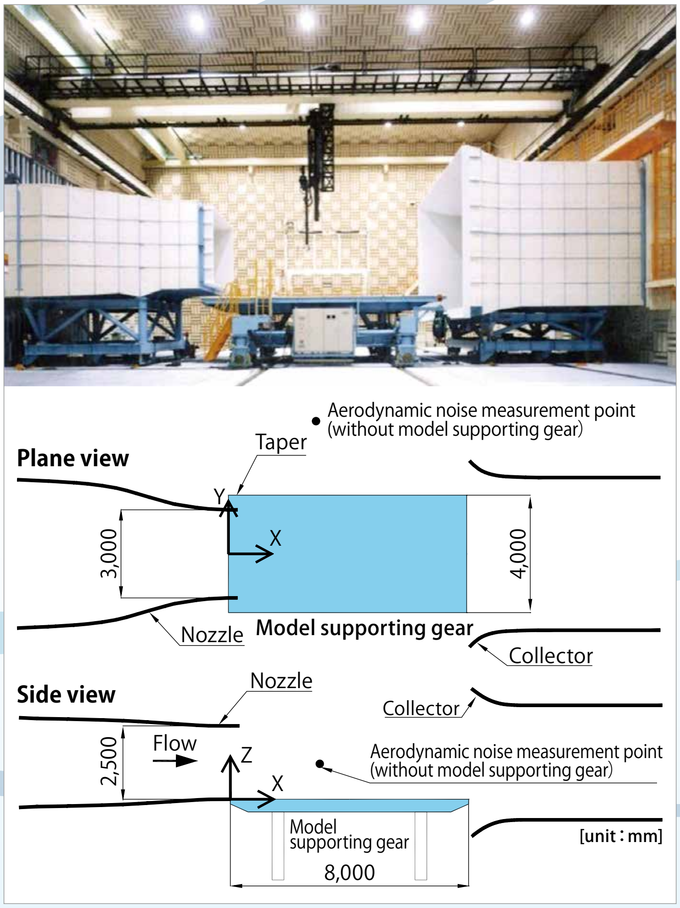
The Maibara Wind Tunnel has two types of test sections, open and closed, which are used depending on the purpose of each wind tunnel test. The open type test section has a width of 3 m, a height of 2.5 m, and a length of 8 m. This type of section allows testing of full-scale components (e.g., a pantograph). A maximum wind speed of 400 km/h (111 m/s) can be achieved,



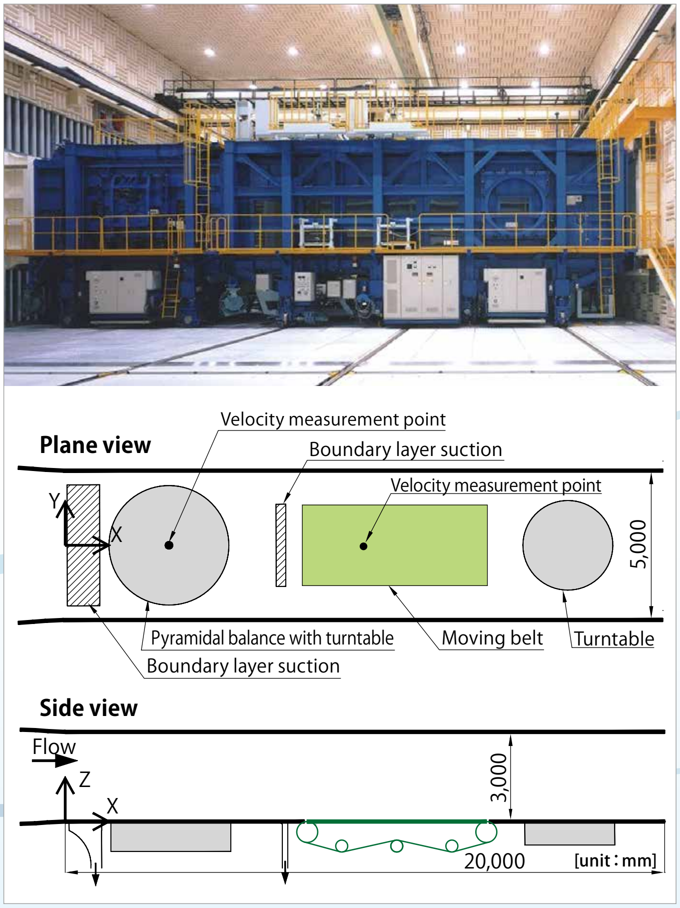
General arrangement

Specifications

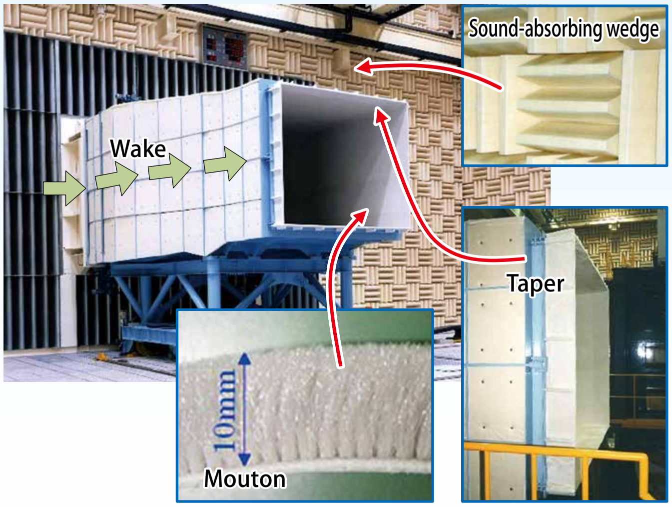
Item	Specifications	
Wind tunnel type	Göttingen-type single return wind tunnel	
Test section type	Open type	Closed type
Test section width & height	3.0m(W) × 2.5m(H)	5.0m(W) × 3.0m(H)
Test section length	8.0m	20.0m
Maximum wind velocity	400km/h (111m/s)	300km/h (83m/s)
Contraction ratio	16:1	8:1
Uniformity of wind velocity	Under ±0.7% at 324km/h (90m/s)	Under ± 0.4% at 288km/h (80m/s)
Turbulence intensity	Under 0.2% at 360km/h (100m/s)	Under 0.2% at 198km/h (55m/s)
Background noise level	75.6 dB(A) at 300 km/h (83 m/s)	
Measurement devices	Sound level meter	6-component balance with turntable
	Beamforming wheel array microphone φ1m, φ4m	6-component wire balance
		Pressure scanning system
	Elliptical acoustic mirror φ1.3m	Built-in-type 6-component balance
Main facilities	Anechoic room 20m(W) × 22m(L) ×13m(H)	Moving belt 2m(W) × 6m(L) 0~60m/s
	Traversing gear	
	Supporting table with turntable	Boundary layer suction system
	Flow visualizing system	
Dimensions	94m Total length, 42m total width, 10m total height, 228m total path length	
Fans	5m in diameter, 12 moving blades, 17 stator blades, 590rpm maximum rotation, 7MW traction motor, Three phase induction motor	



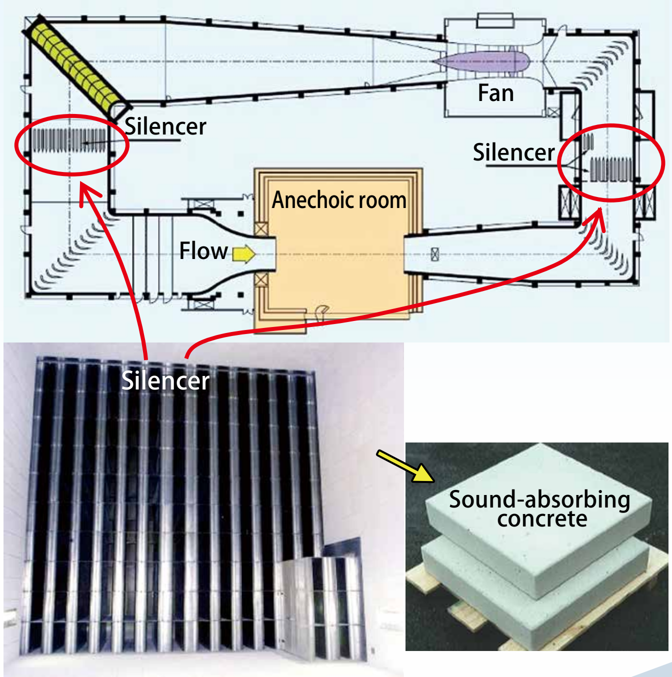
Open type test section



Closed type test section



Noise reduction technology (Air duct)



Noise reduction technology (Anechoic room)

which exceeds the operating speed of the Shinkansen, and is sufficient for R&D on the aerodynamic noise of the Shinkansen. The closed type test section has a width of 5 m, a height of 3 m, and a length of 20 m. This test section is very long compared to its height, which allows scale-model train sets to be tested. In addition, this type can be used for tests that reproduce the boundary layer of natural wind. The maximum wind speed in the closed type is 300 km/h (83 m/s).

Noise reduction technologies

Before the construction of the Maibara Wind Tunnel, most of the available wind tunnels generated large background noise. Therefore, their signal-to-noise ratios were low, making it difficult to conduct aerodynamic noise tests. The Maibara Wind Tunnel has various technologies for reducing noise and makes it possible to conduct aerodynamic noise tests by keeping background noise low.

1) Noise reduction technology in the air duct

- Silencers are installed on the internal cross-sections of the air duct on the upstream and downstream sides of the fan to prevent the noise of the fan from affecting the test section.

- The inner wall of the air duct is covered with sound-absorbing concrete to reduce the noise in the air duct.

2) Noise reduction technology in the test sections

- The entire wall surface, including the bottom surface, of the test section is covered with sound-absorbing wedges to prevent the noise generated by the test model or wind tunnel from being reflected from the walls.

- The jet noise from the nozzle is reduced by reducing the speed difference between the main flow and peripheral flow. For this purpose, the boundary layer was thickened by attaching mouton to the inner surface of the nozzle and slightly widening the nozzle tip. In addition, wake has been produced with outside air taken in to the outer shell of the nozzle.

By adopting these noise reduction technologies, the wind tunnel has achieved low noise performance with a background noise level of 75.6 dB (A) at a wind speed of 300 km/h.

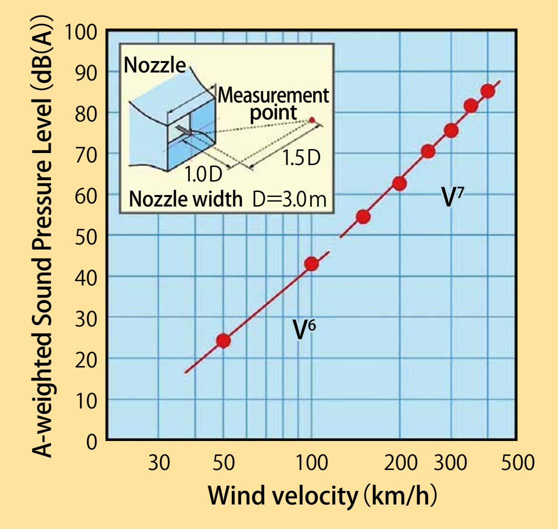
Simulation of ground flow

To simulate the flow between a running vehicle and the ground in a wind tunnel test, we need to eliminate the boundary layer that develops on the floor of the wind tunnel. In the Maibara Wind Tunnel, boundary layer suction devices clear the boundary layer on the floor by sucking it in, and a moving belt suppresses the development of the boundary layer by moving at the same speed as the main flow .

R&D Activities

Research on vehicle running safety against cross winds

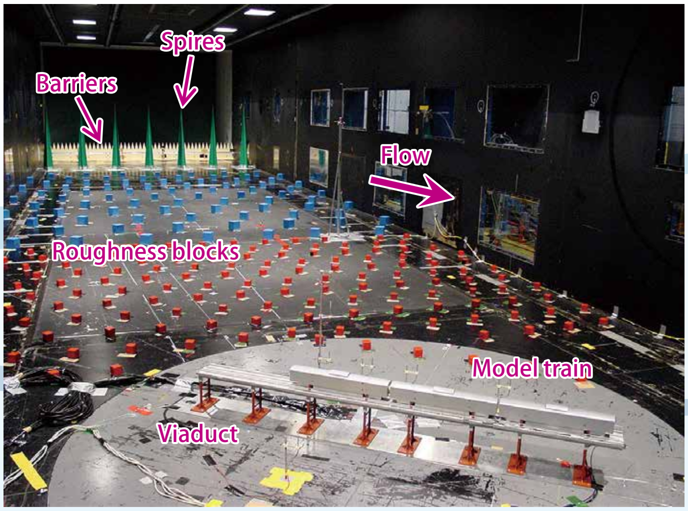
Initially, we conducted wind tunnel tests of the aerodynamic force acting on the vehicle by cross winds by installing only a vehicle within a uniform flow. However, we now know that the aerodynamic force on the vehicle is affected not only by the shape of the vehicle but also by the shape of the ground structures and the wind velocity distribution and turbulence intensity. Thus, we are conducting tests where the ground structures are reproduced in the wind tunnel test section and natural wind is simulated. So far, we have evaluated the coefficients of aerodynamic force by combining five typical vehicle shapes and seven ground structures. We have also evaluated the aerodynamic force of the ground structures that are significantly different in shape from these seven types (e.g., half-bank half-cut structure) and evaluated the effects of windbreak fences. Furthermore, to deepen research on the aerodynamic force acting on the vehicle due to cross winds, we are conducting research on the effect of vehicle running on aerodynamic force and the effect of cross winds on vehicle dynamics in a wind tunnel test of a vehicle model that reproduces the vehicle's suspension system. In addition, the Maibara Wind Tunnel is used extensively in studies on hardware measures such as the installation of windbreak fences, which is one of the effective measures against cross winds (e.g., prechecking the effect by wind tunnel tests).



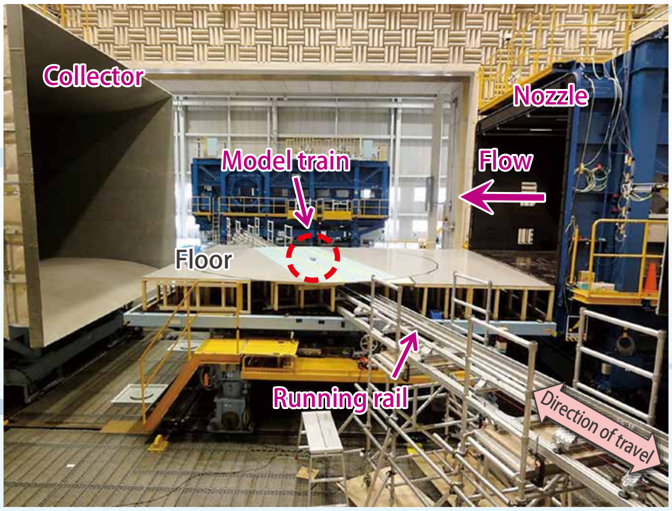
Measured background noise

Research on aerodynamic noise

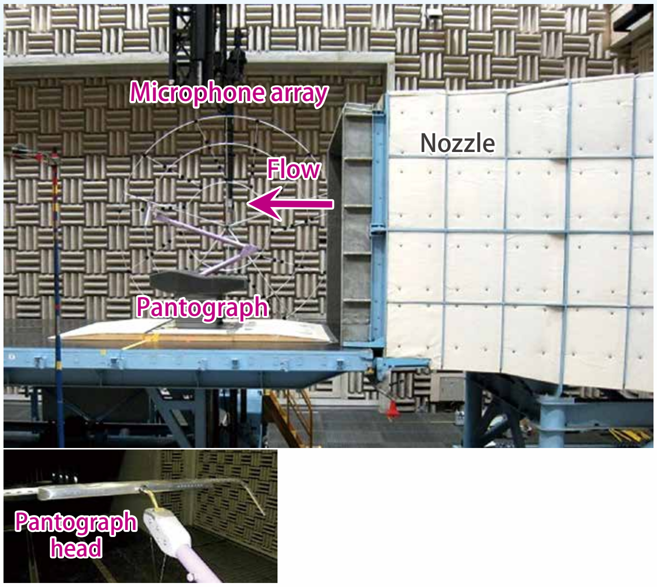
The R&D to reduce aerodynamic noise for the speeding up of the Shinkansen was the primary purpose of the construction of Maibara Wind Tunnel. So far, we have conducted aerodynamic noise reduction R&D for current collection equipment including pantographs and insulators, which has greatly contributed to the speeding up of the Shinkansen. The aerodynamic noise from pantographs is known to be greatly influenced by the pantograph head. However, the aerodynamic lift acting on the pantograph head during high-speed running must be stable. Thus, focusing on the cross-sectional shape of the pantograph head and the positional relationship between the pantograph head and its support, we are proceeding with R&D on pantographs that achieve both the reduction of aerodynamic noise and the stabilization of aerodynamic lift characteristics.



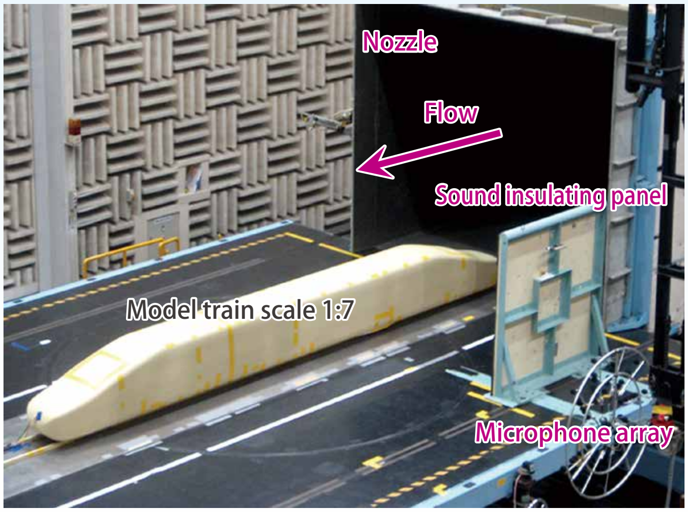
Wind tunnel tests for the train model on the viaduct under crosswind



Moving model rig



Measurement of aerodynamic noise from pantograph



Measurement of aerodynamic noise from bogie-section

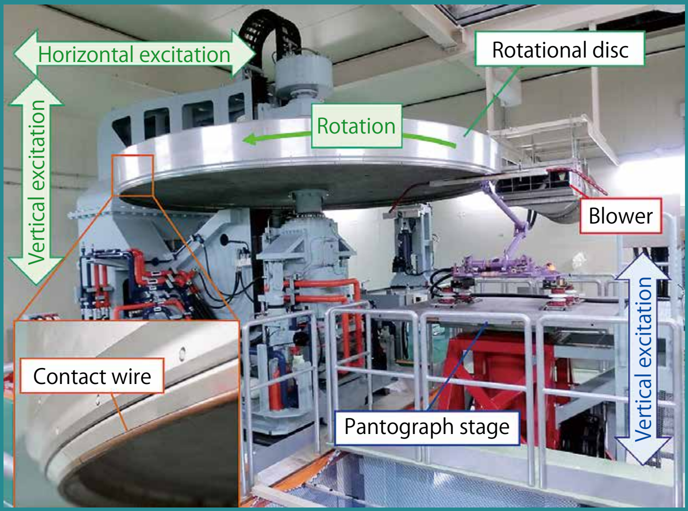
Meanwhile, the R&D up to now has reduced the aerodynamic noise of the current collection equipment, and we predicted the wayside noise from Shinkansen using field test results. As a result, we clarified that the vehicle's bogie section is one of the main sources of aerodynamic noise in addition to the current collection equipment. Our wind tunnel test of the noise of the bogie-section at the Maibara Wind Tunnel has shown that this noise is effectively reduced by suppressing air flow into the bogie section using deflectors installed before and after the cavity of the bogie section.

Conclusion

The large-scale, low-noise Maibara Wind Tunnel has contributed to R&D on railway vehicles conducted by RTRI and JR companies for 25 years since its completion. In 2016, the renewal work of the motor (the "heart" of the wind tunnel), which drives the fan, and the inverter, which supplies electricity to the motor, was completed successfully. We would like to continue to contribute to the R&D of aerodynamic issues of railways by taking advantage of the world's top-class wind tunnel.

Replacement of motor

High-Speed Test Facility for Pantograph / OCL Systems



Appearance of HiPaC

Performance of HiPaC

Device	Specification		
Main Machine	Rotational speed	Max. 500 km/h	
	Vertical vibration	Frequency	≤ 27.8 Hz
		Amplitude	Max. 100 mm*1
		Waveform	Sine wave or other*2
	Horizontal vibration	Frequency	≤ 5 Hz
		Amplitude	Max. 300 mm*1
		Waveform	Triangular wave, sine wave, or other*2
Pantograph stage	Elevating amount	1600 mm	
	Vertical vibration	Frequency	≤ 10 Hz
		Amplitude	35mm*1
		Waveform	Sine wave or other*2
Environmental atmosphere controller	Temperature	-20 to +40 ℃*3	
	Humidity	10 % to 90 %	
Blower	Wind speed	60 to 100 km/h	
Energizing device	Type	AC or DC	
	Voltage	100 to 600 V	
	Current	≤ 1000 A (10-step control)	

*1 Depends on the frequency.
*2 Can be vibrated with any waveform by inputting an external signal.
*3 When the main machine is active (controllable at -25 to +40 ℃ at a atandstill)

RTRI has developed a new test facility “High-Speed Test Facility for Pantograph/OCL (Overhead Contact Line) Systems (HiPaC)” at our Kunitachi laboratory, in order to carry out the following research and development:

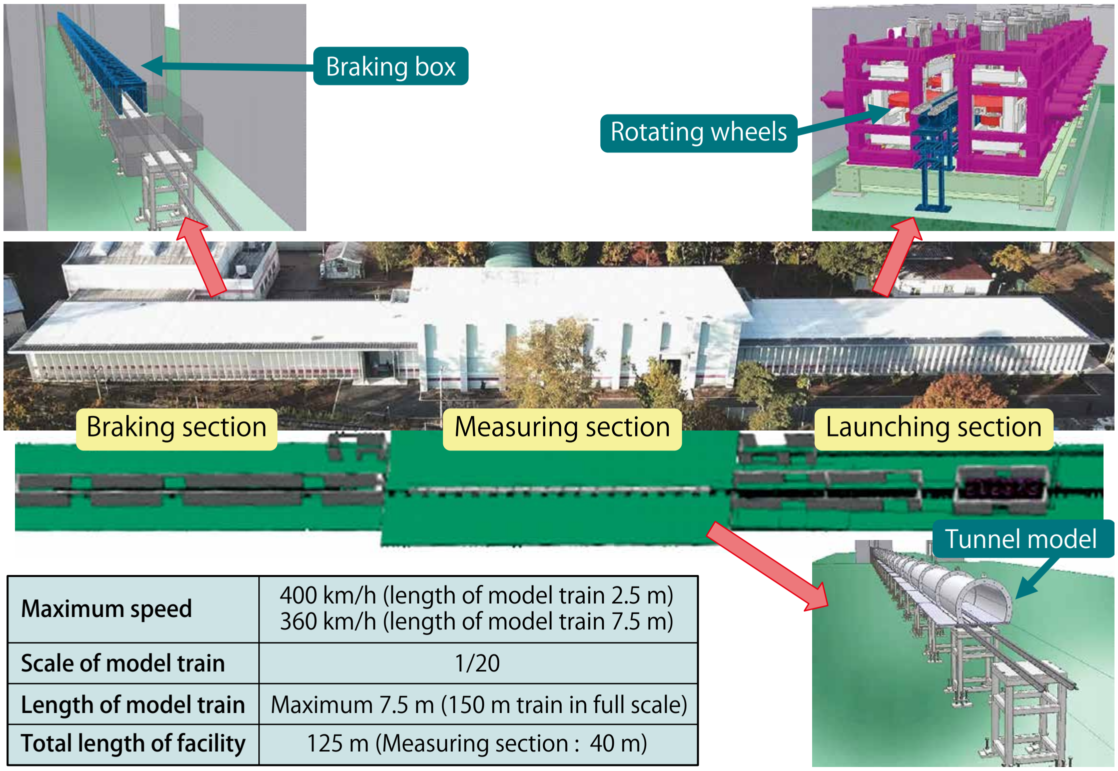
- Evaluate current collection performance of pantographs,
- Evaluate current collection performance of pantographs,
- Develop pantographs for high-speed trains with low-noise and large current collection performance,
- Develop contact strips with improved wear resistance,
- Analyze causes of failure by reproducing power supply and environmental conditions, sliding, and vertical and lateral displacement of the contact wire.

To achieve these, HiPaC can carry a large current (up to 1,000 A) while reproducing high-speed sliding (up to 500 km/h). **Appearance of HiPaC** shows the appearance of HiPaC, which is composed of the following main components:

- Main machine: a rotating disk that reproduces the OCL lateral position, vertical vibration, and sliding.
- Pantograph stage: allowing an actual pantograph to be installed and reproducing the vertical vibration of the vehicle.
- Energizing device: supplying electricity to the pantograph.
- Environmental atmosphere controller: controlling the temperature and humidity in the test chamber.
- Blower: reproducing the cooling of the pantograph-head due to the oncoming wind during running.

Performance of HiPaC summarizes HiPaC’s performance. We intend to use HiPaC to develop a new pantograph with high performance.

(**Tatsuya Koyama**, Senior Researcher,
Current Collection)



Maximum speed	400 km/h (length of model train 2.5 m) 360 km/h (length of model train 7.5 m)
Scale of model train	1/20
Length of model train	Maximum 7.5 m (150 m train in full scale)
Total length of facility	125 m (Measuring section : 40 m)

Overview and specification of low noise moving model test facility

Low-Noise Moving Model Test Facility Completed at RTRI

A low noise moving model test facility was newly completed at RTRI. This test facility, featuring the world's highest performance in its class, is capable of launching a 1:20 scale model train with a real, 3-dimensional nose shape at the maximum speed of 400 km/h, and accurately reproducing the air flow and turbulence created by a running train. It was completed on July 10, 2020 and testing began on October 29, 2020.

[Planned testing and experiments]

The low noise moving model rig will be used to analyze the air flow and pressure fluctuations caused by various three dimensional train and influstructure shapes. The followings are examples of planned testing: (1) experiments to analyze the aerodynamic phenomena caused by a passing train, (2) experiments to reduce micro-pressure waves by optimizing the shape of the train's nose, and (3) gathering data to develop numerical simulation methods.

Measuring section

(**Tokuzo Miyachi**, Senior Researcher,
Heat & Air Flow Analysis)

Mr. Nakamura of RTRI Commended for his Contribution to Standardization Activities

Mr. Kazuki Nakamura of RTRI was given the Year 2020 Award for Contribution to Standardization by the Railway Technology Standardization Survey Committee. The award giving ceremony was held on March 31, 2021 in Tokyo.

Award winner :
Mr. Kazuki Nakamura, Laboratory Head, Telecommunications and Networking, Signalling and Transport Information Technology Division

Award winning achievement :

Since 2017, Mr. Nakamura has contributed to review activities in Japan as a member of the task force and panels for railway telecommunications of the International Telecommunication Union (ITU-R) and the Ministry of Internal Affairs and Communications. In addition, he participated in the International Special Committee on Radio Interference of the International Electrotechnical Commission (IEC/CISPR/SC B/WG 2) as an international expert for more than 10 years and contributed to domestic and international review activities.

He joined the Japanese delegation for the 2019 World Radiocommunication Conference (WRC-19) under ITU-R. He was given the award because he presented Japanese views at the conference, succeeded in reflecting these views in the resolutions, and is expected to further contribute to the international standardization efforts.

*The Award for Contribution to Standardization is given to persons who contribute to international and domestic standardization activities in the railway field. This award was first made in 2007 by the Railway Technology Standardization Survey Committee (Chairperson: Hiroyuki Osaki, Professor of the University of Tokyo, Secretariat: Ministry of Land, Infrastructure, Transport and Tourism and RTRI). Its purpose is to support the activities of award winners and raise the awareness of the importance of standardization among others working in the industry. In particular, the Award for Contribution to Standardization is given to someone who is expected to continue to contribute to standardization.

Railway Technical Research Institute