Toward Railway Innovation
Ascent

Railway Technical Research Institute

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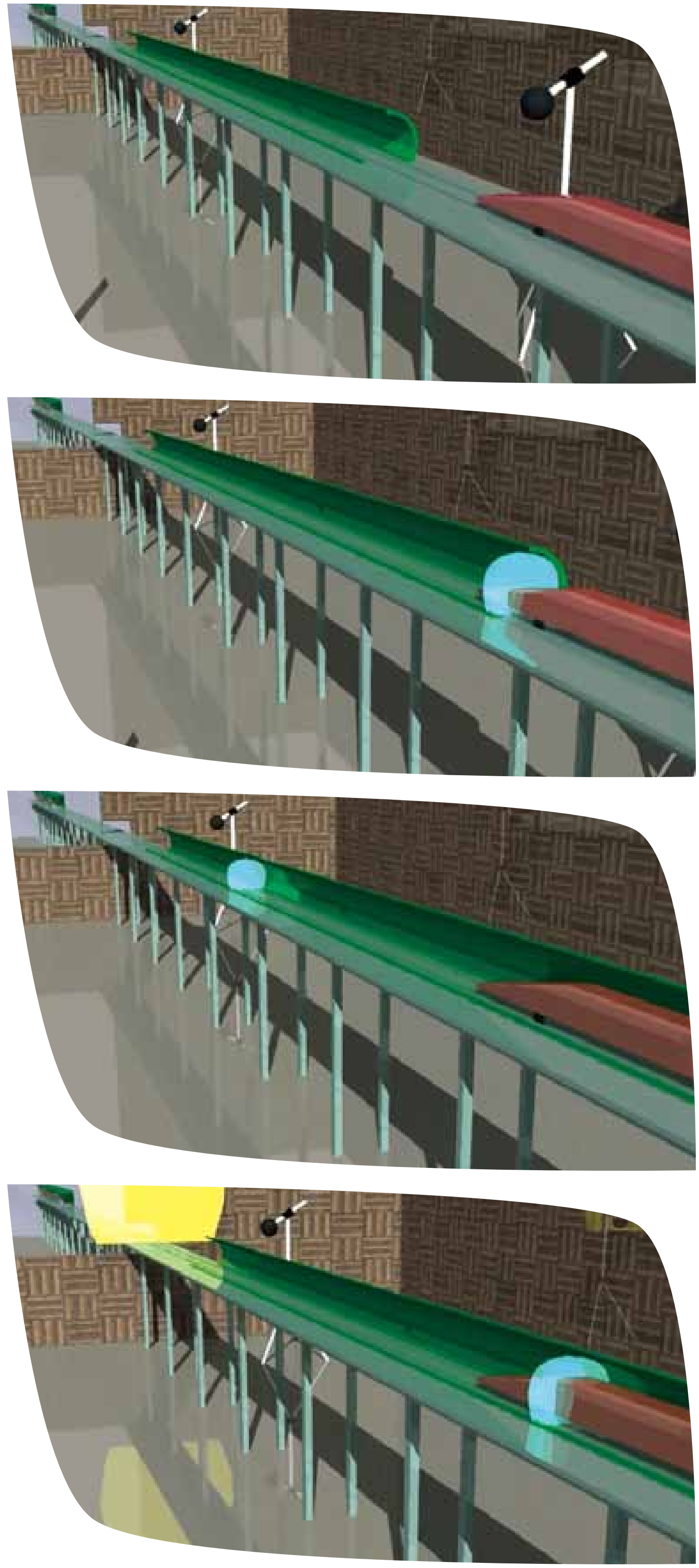
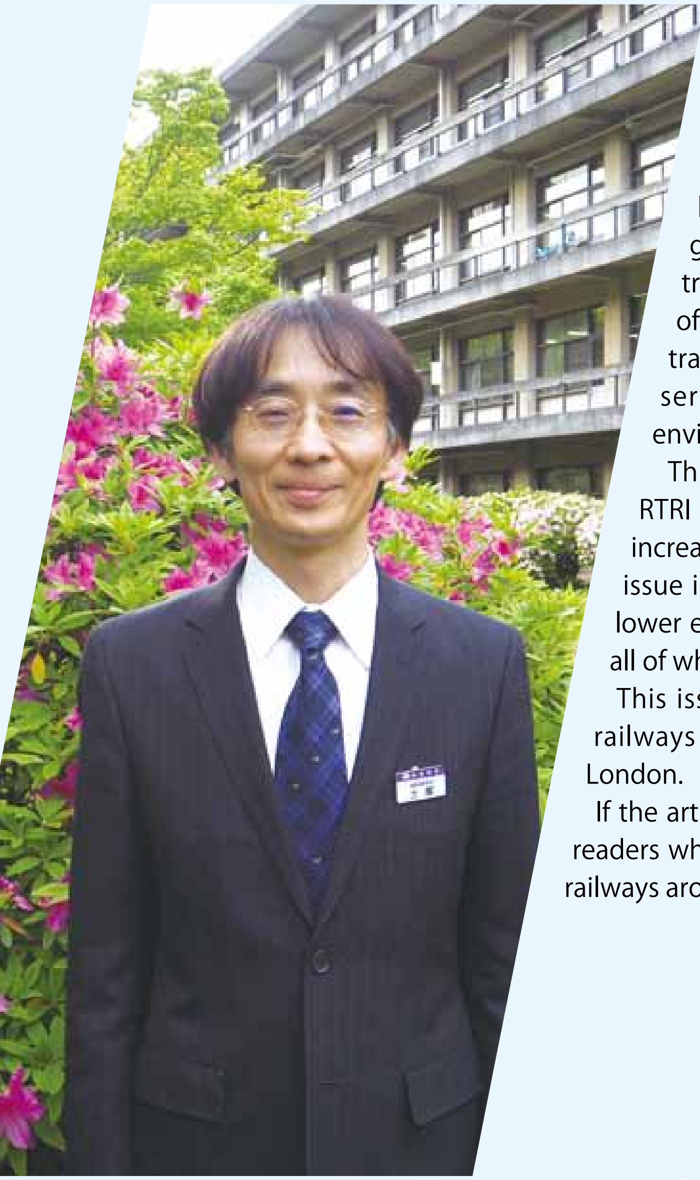
Faster and Energy-efficient Railway





Mr. Ryuji Tsuchiya
Managing Editor
(Director, International Division, RTRI)

Over the last decade, the world's circumstances concerning transport industries have greatly changed with emerging, low-cost air carriers, spreading ride-share services and collapsing fares in long-distance bus services. Furthermore, we will have to expect that growing use of autonomous driving options will change the world's transport scene more drastically. In order to improve competitiveness of railways over other transport modes and increase their share in the transportation market, we have to provide customers with transport services producing higher customer satisfaction while reducing environment impacts and energy costs.

This issue of Ascent features an overview of some of the new fronts RTRI has been pursuing with the goal of contributing to further speed increases and improving customer experience. The particular focus of this issue is on research efforts carried out to realize improved ride comfort, lower energy consumption, and reduced impact on wayside environment, all of which are essential factors for further speed increases.

This issue also presents an article on the current status of high-speed railways in the UK by Professor Roderick Smith at the Imperial College, London.

If the articles contained in this issue of the *Ascent* provide assistance to our readers who are involved with railways and contribute to the development of railways around the world, I could not be happier.

Cover:
At RTRI, a new test facility to analyze the mechanism of micro-pressure waves is under construction. A model train runs through the model tunnel at 400 km/h and generates micro-pressure waves.

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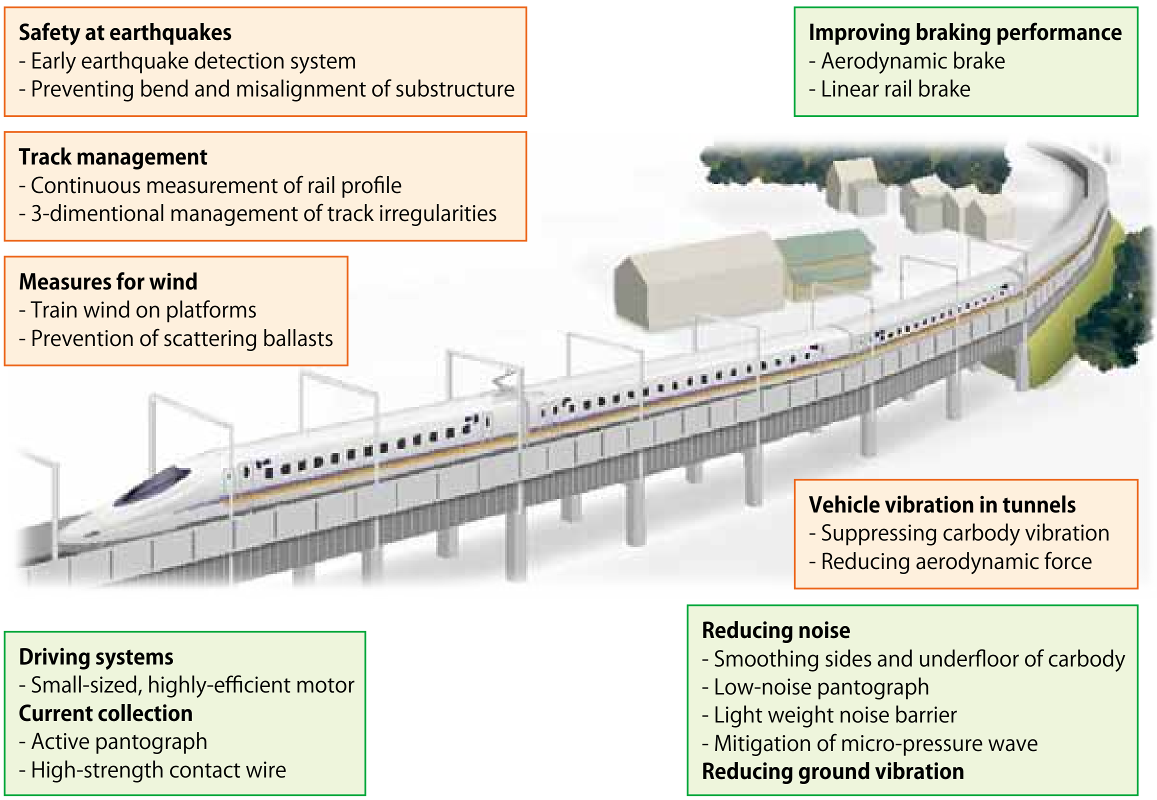
The Necessity of Trains Becoming Faster, More Comfortable and Energy-efficient



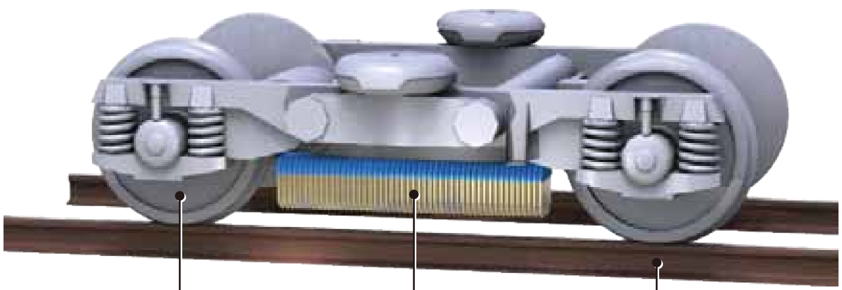
Technical challenges for higher speed train

Dr. Atsushi Furukawa
Director
Research & Development Promotion Division

Superiority of railway over other modes of transportation

Railway transportation offers quicker delivery than motor vehicles and marine vessels and operates at higher energy efficiency and greater transport volume than motor vehicles and airplanes. While trains cannot travel as fast as airplanes, airports are often located a considerable distance from city centers, which can put trains on a par with airplanes in terms of the total time spent traveling between cities. In Japan, travel by rail has a higher share than airplanes as the preferred means of transportation where it takes no more than 4 hours by rail to travel from one city to another. This is called "the 4-hour factor."

At a time when global warming is an issue that needs to be tackled, railways offer high energy efficiency. To further enhance the competitiveness of rail travel, it will be crucial to make additional progress in cutting travel time and improving comfort, especially in the case of high-speed



Rail brakes

railways. *Ascent Vol.4* deals with some of these endeavors and other related research and development programs currently being pursued at RTRI.

Technologies indispensable in achieving higher speeds and improving the quality of service

Technologies for achieving higher speeds and more efficient operating practices

Improvement in braking performance

Trains may be designed to run faster, but they must also be able to stop safely. Therefore, higher speeds must be supported by sufficient braking force. At RTRI, programs are underway on the improvement of disc brake performance as well as on the development of aerodynamic braking and rail braking, neither of which relies on wheel/rail contact. By combining these non-contact brakes with electric and mechanical brakes, RTRI aims to develop a brake system that offers a desired braking distance even with a higher initial braking speed.

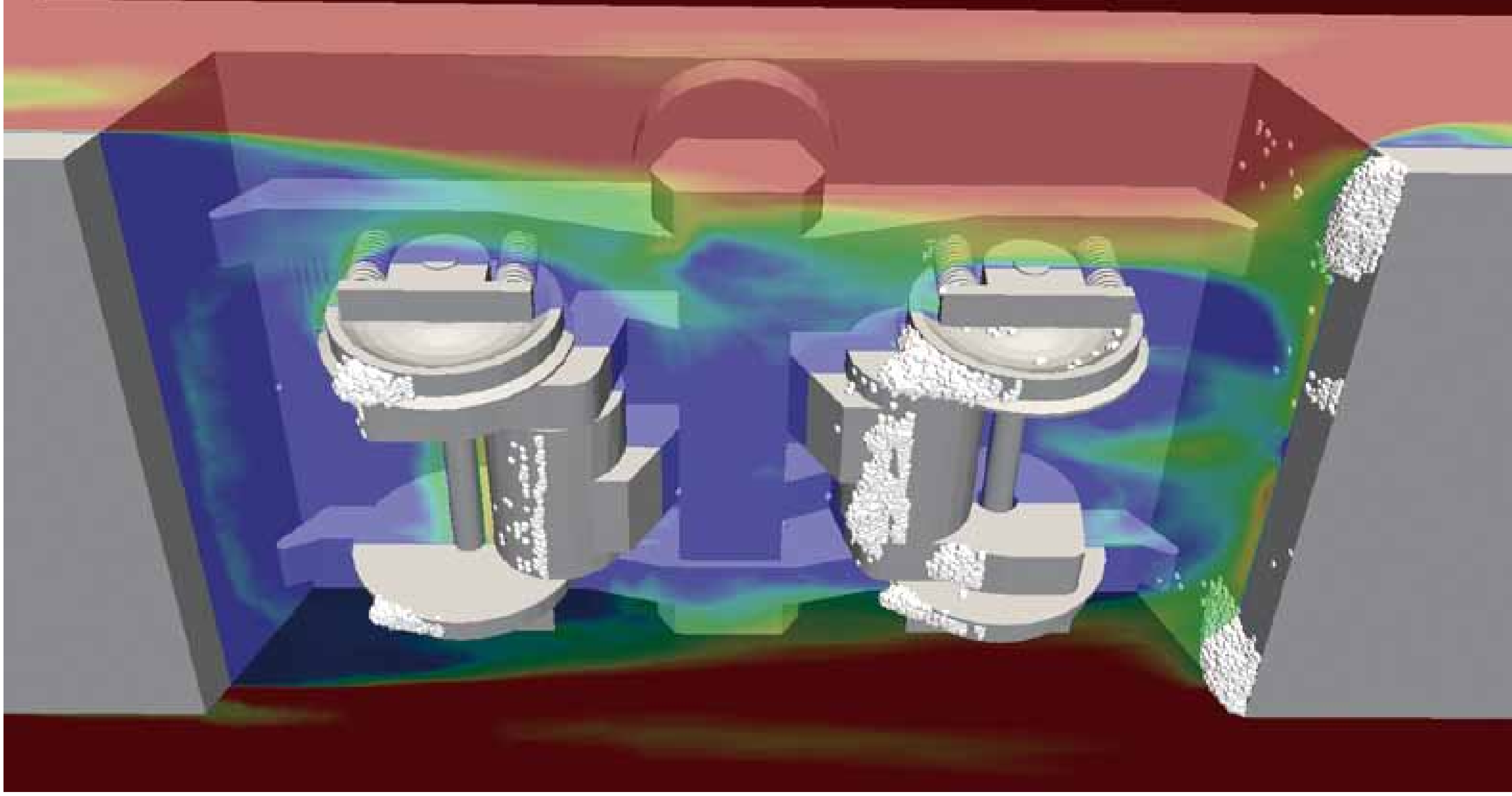
Improvement in current collection performance

Trains cannot run faster than the wave velocity of contact wire, which is a function of wire tension and structure. To increase wave velocity to allow trains to run faster, stronger contact wire needs to be erected and tensioned more tightly. In the case of pantographs, on the other hand, they need to be able to follow the movement of contact wire being shaken, and, at high speed, offer stable aerodynamic upward force and low noise at the same time, two conflicting aerodynamic requirements. As the Shinkansen system is required to meet the stringent environmental quality standards in place here in Japan, achieving higher running speed will also require pantographs to meet their corresponding requirements regarding both current collection and low noise.

Improvement in environmental performance

As trains run faster, they generate greater noise and more intense vibration. While the frequency and power of noise vary depending on the source of the noise, higher running speeds can create new types of noise. Measures have been taken to reduce aerodynamic noise such as by reshaping pantographs and the surrounding areas and by smoothing out the upper surfaces of vehicles. Measures have also been taken to reduce the noise of wheels rolling on rails such

Tunnel entrance hood



Simulation modelling for a railway vehicle running in snow is now developping. It is not practical to conduct tests with a running train on site in a specific snow-wind condition. Numerical simulations are useful to grasp the phenomena of snow accretion on a bogie-part in detail.

as by smoothing out rails and wheels. More recently, there arose the need to reduce additional types of noise including aerodynamic noise emitted from the cavities in bogies.

With non-ballasted tracks such as slab tracks, when a train enters a tunnel, compression waves are generated, traveling through the tunnel without being attenuated and emitting an impact noise as they radiate from the exit. The phenomenon, called “micro-pressure waves”, has been an issue of concern. To help resolve the issue, tunnel entrance hoods have been installed and the front end of vehicles have been reshaped. Further improvement, however, will be needed.

Technologies for improving the quality of service

Improvement in ride comfort

While technologies for reducing braking distances and mitigating noises are indispensable in achieving faster running speeds as discussed above, it is also important to improve ride comfort to stay competitive against other means of transportation. Normally, as running speed increases, track-generated vehicle vibration accelerates and with that the elastic vibration of car bodies and cabin noise also increase. With Shinkansen, car-body tilting systems for curves and active suspensions, both using air springs, help improve lateral ride comfort. At RTRI, efforts are being made to develop a vibration control system that combines variable attenuation dampers with actuators to improve vertical ride comfort.

In addition to the wayside noise reduction measures discussed earlier, cabin noise reduction measures are also important for ride comfort. Cabin noise can be classified generally as structure-borne sound from the bogies and sound transmitted through the cabin walls. At RTRI, development programs are underway on a suspended cabin floor to separate the floor from the bottom of the car body for noise insulation and on vibration damping elements that would be installed in vibration transmission routes between the bogies and the cabin.

Measures for cold weather operations

In Japan, a heavy-snowfall country by world standards, snow and ice have been a problem since the opening of the Tokaido-Shinkansen Line. If snow or ice that has accumulated on car bodies falls during high-speed operation, trackside facilities, and even wayside buildings and automobiles, can suffer damage as a result. Delays and other disruptions related to snow have been reduced substantially through the installation of water-sprinkling, snow-melting equipment and the improvement of track structures. However, with the Hokkaido Shinkansen Line being extended in cold and heavy-snowfall regions, developments are planned for further anti-snow measures. Specifically, simulation modeling is underway to reproduce snow accumulation on bogies and the surrounding areas and, in combination with related wind tunnel tests and model experiments, improve

A scale model of half cross-section of double-skinned bodyshell made from a flame-resistant magnesium alloy

the shapes of bogies and the surrounding areas to limit the accumulation of snow.

Snow control measures on the ground include snow removal, snow melting, wetting of snow by water-sprinkling, and snow storage. Related measures on the vehicle include snow accumulation prevention measures and snow melting accomplished by heating. In the inland areas of Hokkaido where temperature can drop to -30℃ (-22℉), water-sprinkling cannot be used as the water used will freeze. Therefore, each district will need to adopt snow control measures that are appropriate for the unique local weather conditions.

In cold districts, issues related to low temperatures are anticipated to occur more frequently, including the performance deterioration of lubricating oils used in various parts of the vehicles, wheel/rail adhesion, and frost formation on the contact wire resulting in contact loss. RTRI has been pushing R&D efforts to be able to appropriately address these issues.

R&D for reduction in energy consumption

To further enhance the superiority of railways, mentioned at the beginning of this paper, over other means of transportation, reduction in energy consumption and increased running speeds are a must.

Energy consumption can be reduced by making vehicles lighter. RTRI developed a press-forming, weight reduction method for bodyshells based on a structure optimization algorithm. RTRI has also been pursuing bodyshell weight reduction using a flame-resistant magnesium alloy.

Along with car body weight reduction, RTRI has been trying to cut energy consumption through the efficient use of electric power. Specifically, for efficient use of regenerative energy, RTRI has been conducting development programs on train acceleration/deceleration control across an entire railway network, delivery voltage control at substations, reduction of feeding loss using superconductive feeders, and a flywheel energy storage system using superconducting magnetic bearings.

Conclusion

High-speed rail service successfully debuted in 1964 with the opening of the Tokaido-Shinkansen Line. Today, high-speed trains form the backbone of intercity transport, primarily in Europe and East Asia. On the other hand, competition with other means of transportation has been intensifying, namely low-cost airlines who have been experiencing a rapid market growth and a network of expressways which has been extending its coverage. Fifty-four years ago, RTRI's predecessor, the R&D arm of Japanese National Railways, opened the door for high-speed rail service. Continuing with the creative spirit, RTRI will vigorously keep developing innovative technologies to further enhance the competitiveness of rail travel.

Reduction of Elastic Vibration of Car Bodies and Internal Noise

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Chief Researcher
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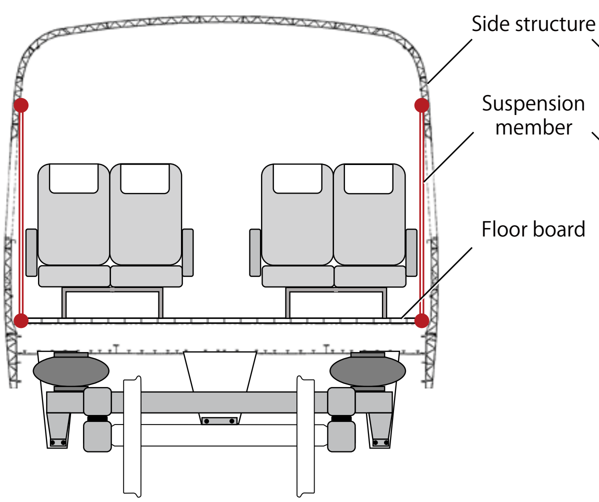
Ride comfort and noise are two of the most significant factors affecting train passengers' overall comfort. Frequencies of vibration from several Hz to several dozen Hz affect ride comfort and those from several dozen Hz to several kHz affect noise. To offer higher comfort to passengers, appropriate measures must be taken to mitigate the magnitudes of these factors.

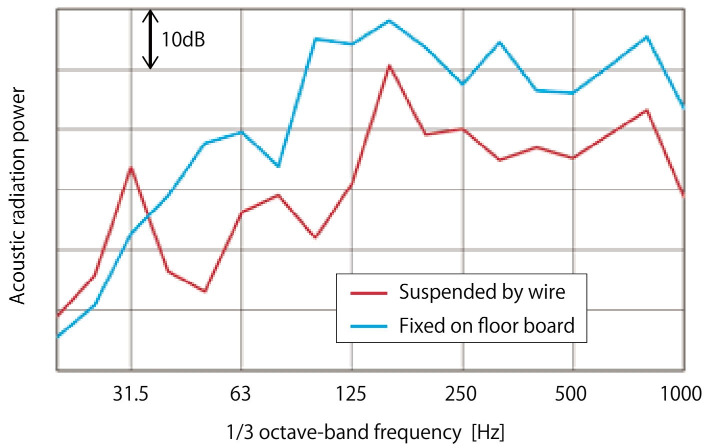
Reducing internal noise in vehicle

The internal noise of railway vehicles can be divided into structure borne sound, which is generated as the vibration of bogies etc. is transmitted to the floor board and interior decoration, and sound transmitted from the outside through the bodyshell and interior decoration. Since noise reduction measures vary depending on the types of noise, a suspended floor has been devised to reduce the structure borne sound transmitted through the floor board. The floor board, which is normally supported by the floor structure, is instead suspended from the side structures. With this method, the vibration of the floor board is expected to be reduced as structure borne sound comes only through the side structures, whose vertical vibration is moderate.



The floor board is suspended from the side structures to reduce the structure borne sound.

RTRI conducted an experiment of the suspended floor with a Shinkansen type test vehicle.



The comparison of the power of floor board vibration shows that the suspended floor board can reduce the structure borne sound in the range below 1000 Hz.

RTRI made a test vehicle installing a suspended floor to conduct an experiment. In the experiment, wires were used as the suspension members. The power is calculated from the measured floor board vibration in a stationary vibration test. The results indicate the power is around 5–10 dB lower on the suspended floor structure in the range below 1000 Hz.

Reduction of Vertical Vibration of Vehicles through Control Technology

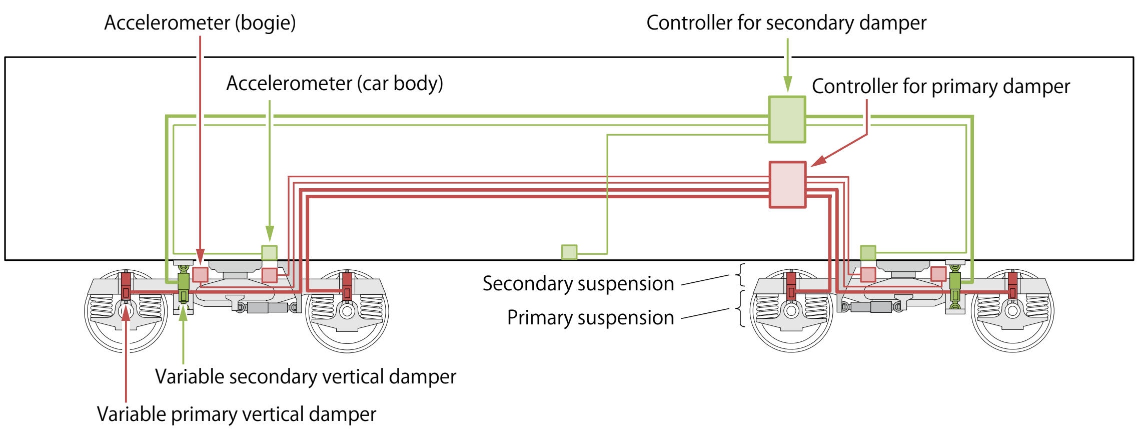
In general, as train running speeds increase, vibration contributing factors grow in intensity, causing vehicles to vibrate more severely and reducing ride comfort. One of the most effective technologies involved in maintaining ride comfort under such conditions is the "vibration control system", which is installed on nearly all Shinkansen vehicles to counter lateral vibration. As a result, lateral ride comfort has even been improved on Shinkansen vehicles despite the fact that they now run faster than ever before. On the other hand, no solutions have ever been introduced that substantially improve vertical ride comfort. With that in mind, RTRI has been active in developing a vertical vibration control system for high-speed trains.

Vertical vibration damping system configuration

The diagram immediately below shows the vertical vibration damping system being developed for high-speed trains. The sub-system shown in green measures vertical vibration of the car body and controls the dampers installed between the car body and bogies in such a way as to reduce the vibration. The other sub-system, shown in red, measures vertical vibration of the bogies and, based on the measurements, estimates the elastic vibration of the car body (which is accompanied by car body deformation) and controls the dampers installed between the axle boxes and bogies in such a way as to reduce the vibration.

Results of vibration testing using an actual vehicle

To verify the system's intended performance, the system was installed on a vehicle equivalent to the real Shinkansen



The vertical vibration damping system, which consists in principle of two sub-systems, is capable of reducing vibrations (parallel vertical movement, pitching, rolling and primary flexural vibration) typically generated on vehicles running at high speed.

vehicle and the assembly was subjected to vibration testing simulating actual operation on the Shinkansen track. The results showed substantial reduction of vertical vibration of the car body and improved ride comfort.

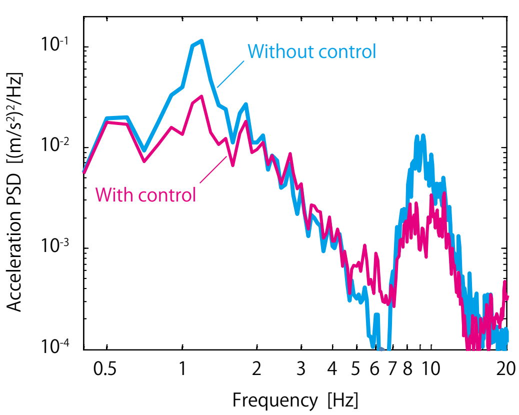
Future plans

Based on the results obtained, the system will be improved further for testing on actual Shinkansen vehicles. Efforts will be continued to ultimately utilize the system in practical applications, thereby helping to improve the ride comfort of high-speed trains and, more broadly, the quality of service.

Conclusion

Solutions to ride comfort and internal noise issues need to be, in general, lightweight, low-cost and something that will not substantially alter the current structure. That increasingly leaves us with few options that appear readily applicable, making it more plausible to try something totally new. Going forward, we will plan to expand our field of vision in our R&D to include possibilities that appear even a little unusual and continue our efforts for practical application.

A prototype of virtical vibration damping system was tested on the rolling stock test plant in RTRI.



The graph shows examples of vertical vibration reduction by the system as measured directly above a bogie in the vibration test. Both rigid-body vibration (not accompanied by car body deformation) at around 1 Hz and elastic vibration (accompanied by car body deformation) at around 9 Hz are shown to be substantially, thus achieving improvement in ride comfort.

Weight Reduction for Energy Efficiency and Higher Speed

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Materials Technology Division

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Increasing the running speed of trains not only increases energy consumption but also tends to increase vibration and noise since the force applied on the tracks will also increase. As such, it becomes increasingly necessary to reduce the weight of the car body to achieve higher running speed of trains while controlling energy consumption, noise, and vibration. Here, we introduce two different approaches that are intended to reduce the weight of the car body.

Use of light-weight metals

Most modern trains use stainless steel and aluminum alloy for the body structure. While some weight reduction has already been achieved by using aluminum, i.e., light metal, we could expect to further reduce the weight if we are able to use magnesium whose density is about two thirds of that of aluminum.

The advantage of using magnesium is not limited to its light weight – magnesium is abundant in the earth's crust, and thus it is relatively easy to get. However, one of the problems is that magnesium can be flammable. Thus, we have developed a noncombustible magnesium alloy, by adding calcium to typical magnesium alloys, for use in car bodies. We have successfully tested the new material to verify that it is noncombustible up to an ambient temperature of 600℃. The test was performed by directly heating a plate of the noncombustible magnesium alloy. Typical magnesium alloys catch fire at this temperature.

To use the material for the car body structure, various types of sheet metals and sections of different cross-sectional profiles are required. While sheet metals and sections are mainly produced by extrusion, it is generally the case that sections are more difficult to produce than sheet metals. We have successfully produced

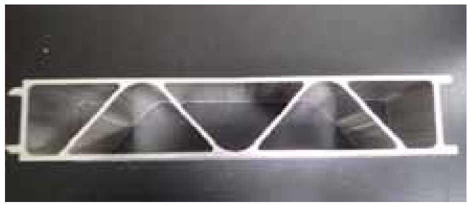
MIG welding by an automatic welding machine

MIG welding of roof structure

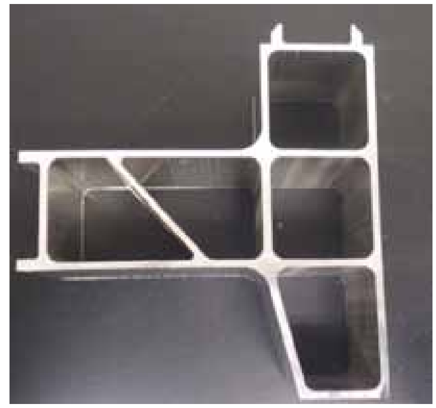
noncombustible magnesium alloy sections to nearly the desired cross-sectional profile to be used for various types of car body structural members. This was achieved by optimizing various parameters such as the symmetry of cross sections, deformation resistance during extrusion, and so on.

The next step was to develop the bonding technology to assemble and join the section members to form a structure. We have tested the MIG (Metal Inert Gas) and FSW (Friction Stir Welding) methods, which are used for welding aluminum alloys to form car body structures, and found that the MIG welding method can produce similar bonds as in the case of aluminum alloys. On the other hand, we have not yet developed a FSW method that can achieve the same level of bonding as with aluminum alloys, as defects are easily produced in bonding areas. Accordingly, further studies are required on the new magnesium alloy material in terms of the basic material data, assembly and working techniques, and bonding techniques.

We have produced a small half section model structure of a car body, by combining the material technology with a number of techniques in production and bonding of various structural members. In particular, we have successfully bonded hollow sections of magnesium alloy to the intended size using the MIG welding method. Although this result cannot be directly applied to actual vehicles, this model is considered a step towards the practical use of noncombustible magnesium alloys on vehicles. While we have to study and verify a number of things before the practical use, we will continue our efforts to develop and accumulate more techniques aiming to further reduce the weight of rolling stock.



Section material for floors and walls



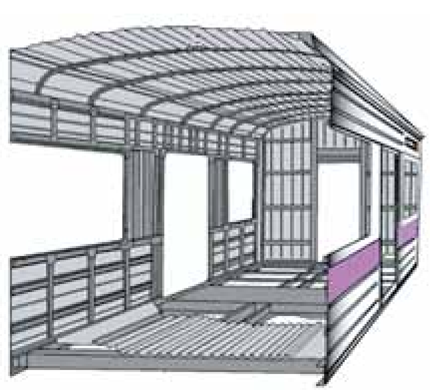
Section material for side beams

Applying new body structures and design methods

To achieve a higher running speed of trains, weight reduction of the car body is required. On the other hand, to keep passengers comfortable, it is also necessary to enhance the rigidity of the car body. However, since that generally leads to weight increase, it becomes a difficult problem to satisfy the weight reduction and rigidity requirements at the same time.

Conventional vehicles have a framed structure. In this, the side posts, transverse beams, and other members are joined together to make a discontinuous structure. Also, the large number of parts and complicated structure tend to make it difficult to reduce weight and increase rigidity. To solve the problem, we have developed an idea using press forming to make an integral structure of concavo-convex shapes for a light weight and less deformable body structure. To form the new body structure, we have established a rational design method using the structural optimization technique. As a result, a new body structure using press forming has been proposed.

As it is difficult for conventional design concepts to derive proper concavo-convex shapes according to the load applied to the body, a new structural optimization technique has been established. We have verified that a press formed car body can be designed to increase the rigidity and decrease the weight compared to the conventional car bodies that are based on a frame structure.



Conventional vehicles are structurally so complicated that it is not easy to reduce their weight and increase their rigidity.

A light weight and less deformable body is realized with an integral structure of concavo-convex shapes shell by press forming.

Reducing the Air Resistance of Vehicles

Dr. Atsushi Ido
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Introduction

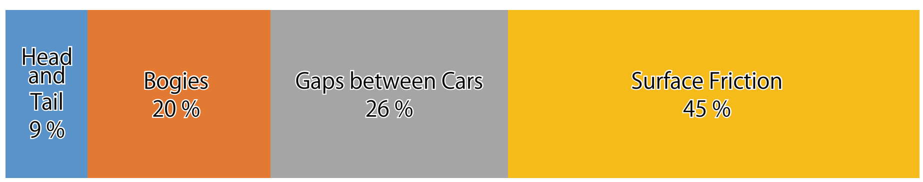
The running resistance of a train, which increases as it runs faster, consists of rolling resistance, which is proportional to the train speed, and air resistance, which is proportional to the square of the train speed. With high-speed trains like Shinkansen, most of the running resistance is accounted for by air resistance. Therefore, reduction of air resistance is vital to achieving faster speed with high energy efficiency.

A Shinkansen train set is extremely long and thin (e.g. a set of 16 vehicles is 400-meter long and 3.65-meter high). The air resistance of its front and rear ends accounts for an extremely small portion of the entire train set's air resistance. Therefore, any improvement in the shape of the front and rear ends would hardly help reduce the train set's air resistance. On the other hand, the air resistance of the intermediate vehicles accounts for nearly all the train set's air resistance. It can be reduced by smoothing the underfloor profile.

While smoothing the vehicles' underfloor profile reduces air resistance, it also increases the cost for producing and maintaining vehicles. Cost effectiveness (energy saving from lower air resistance versus increased production and maintenance costs) therefore needs to be examined. The above shows that reducing the air resistance of vehicles involves accurate examination of possible air resistance mitigation methods and, no less important, other expected effects of the mitigation.

Evaluation of an entire train set's air resistance

Air resistance is typically evaluated by means of wind tunnel tests, actual vehicle tests or numerical calculations. Among these, wind tunnel testing is the most practical in terms of accuracy and costs involved. Presented below is a wind tunnel test from which highly accurate evaluation can be made. Tests conducted in the past using actual vehicles revealed that a solid boundary layer develops on the third vehicle from the front and the following vehicles. This creates a nearly constant flow field below the floor of those intermediate vehicles. Therefore, the air resistance of those intermediate vehicles, or from the third vehicle down, can be regarded as almost constant. Based on the above, the air resistance of an entire train set can be estimated in wind tunnel test by evaluating the air resistance of an intermediate vehicle and then multiplying the evaluated value

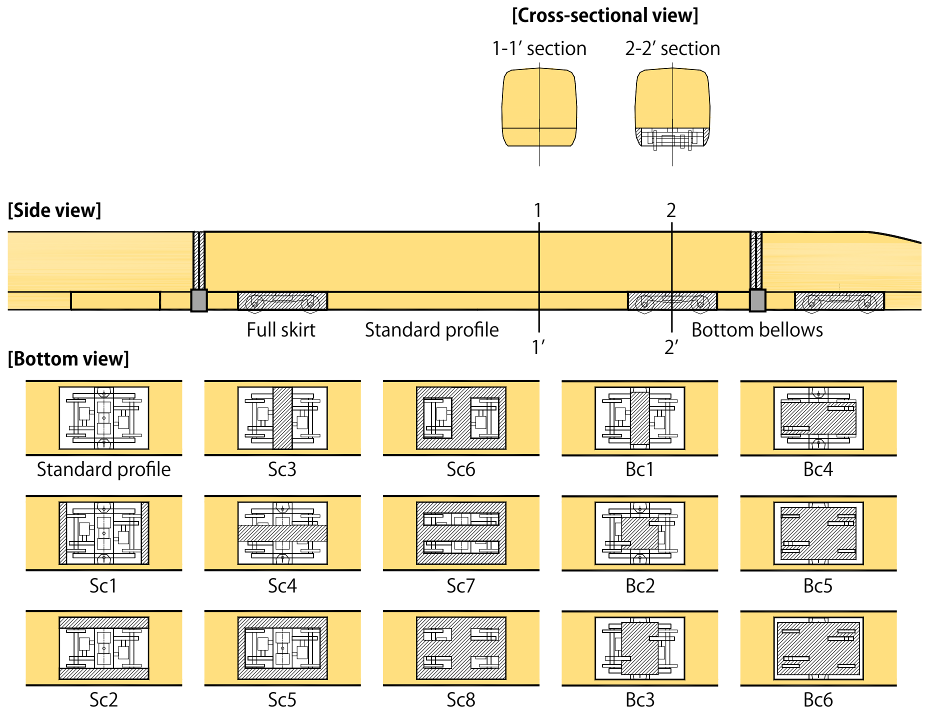


Contribution to aerodynamic drug of corponents in a high speed train of 16 cars

The track surface flow is simulated using a moving belt and a boundary layer suction device. A spire installed on the front vehicle controls the boundary layer formed under the vehicle floors to reproduce the underfloor flow field on the intermediate vehicle.

by the number of vehicles in the train set.

In our test, noncontact LDV (Laser Doppler Velocimetry) flowmeters were used to measure air current fields under the floors of actual vehicles including areas off the vehicles that had not been measurable. The data on the distribution of flows under the floors of intermediate vehicles was then reproduced in wind tunnel tests. In the wind tunnel test, a 1/7 scale model train set of three (front, intermediate and rear) vehicles was used. The underfloor flow velocity of an intermediate vehicle in wind tunnel test is faster than that of actual vehicles. To compensate for this, a spire is installed under the floor of the front vehicle in wind tunnel tests to reduce the underfloor flow velocity. Then the distribution of flow velocity under the floor of the intermediate vehicle can be made to agree with that of actual vehicles, making it possible to highly accurately estimate the air resistance of the entire train set.

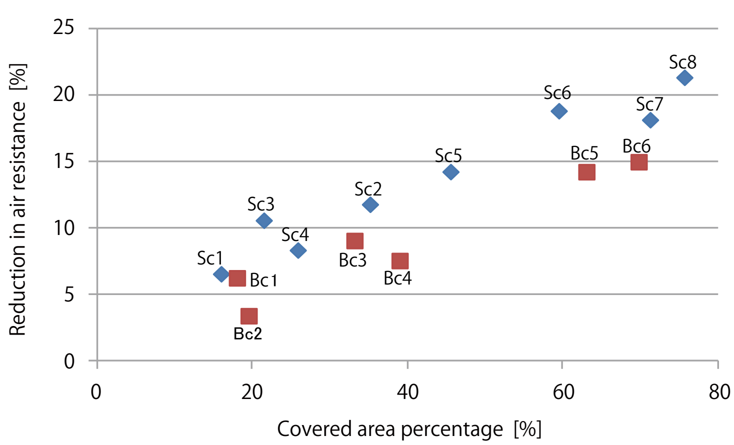


Different Types of Bogie Bottom Covering

Air resistance is reduced by smoothing the underfloor profile of vehicles using bogie bottom coverings and gangway bottom bellows. There are two types of bogie bottom coverings. Sc types are attached to a car body. Bc types attached to a bogie itself.

Air resistance reduction method and its effect

Practical ways to smoothing the surface of actual Shinkansen vehicles include bogie bottom coverings and gangway bottom bellows. Shown below is the effect of bogie bottom coverings on reducing air resistance. The air resistance reduction effect is shown to increase in proportion to the area of the covering under the bogies. It has also been confirmed that installing gangway bottom bellows can reduce air resistance. By combining these and other underfloor smoothing methods, air resistance can possibly be reduced by several dozen percent on older and the latest Shinkansen vehicles.



Air resistance is reduced in proportion to the area of bogie bottom covering.

Future plans

Smoothing the underfloor profile of Shinkansen vehicles increases vehicle production and maintenance costs, but also can be expected to reduce snow accretion to bogies as well as underfloor aerodynamic sound. The smoothing methods will need to be examined further for these and other effects in addition to the reduction in air resistance before they can be introduced on actual vehicles.

Preservation of Environments beside High Speed Lines

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Chief Researcher
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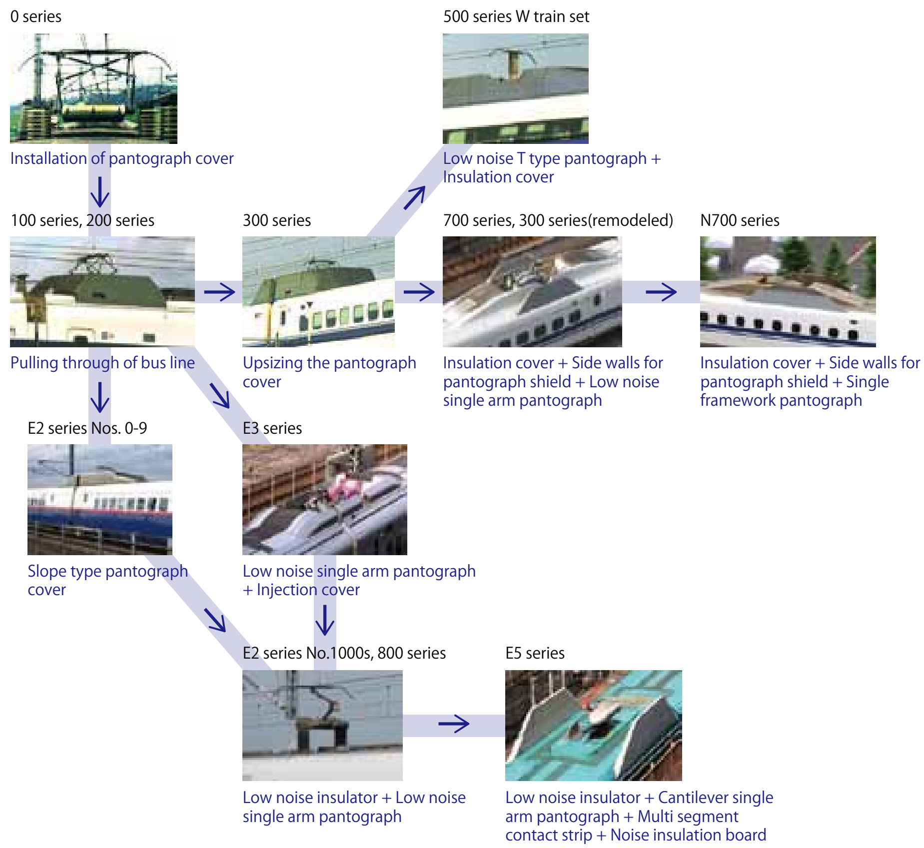


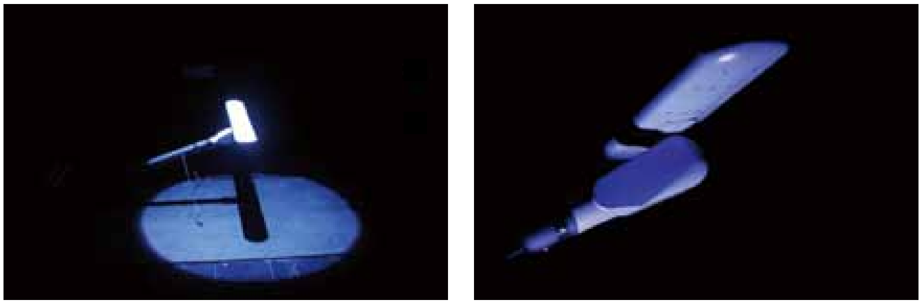
Transition of pantograph for the Shinkansen

Introduction

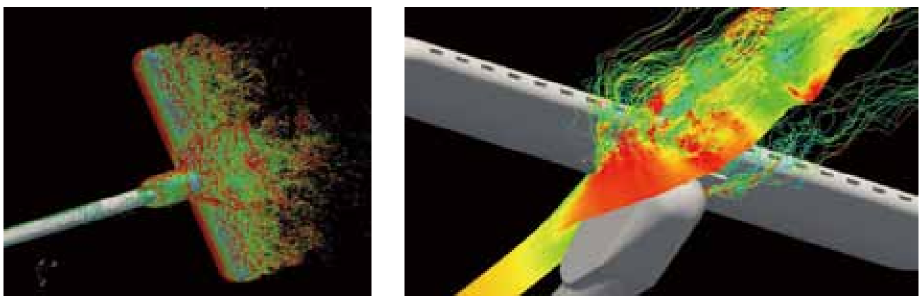
Since the topography of the Japanese archipelago has few plains, the railway has many long tunnels as well as many places where high-speed trains run through densely populated areas. Since both of these affect human life along the railway lines, R&D to address these issues has been continuously conducted; it is not an exaggeration to say that the environmental measures taken with the Shinkansen are always at the top level in the world.

Measures against Overhead Contact Line / Pantograph System Noise

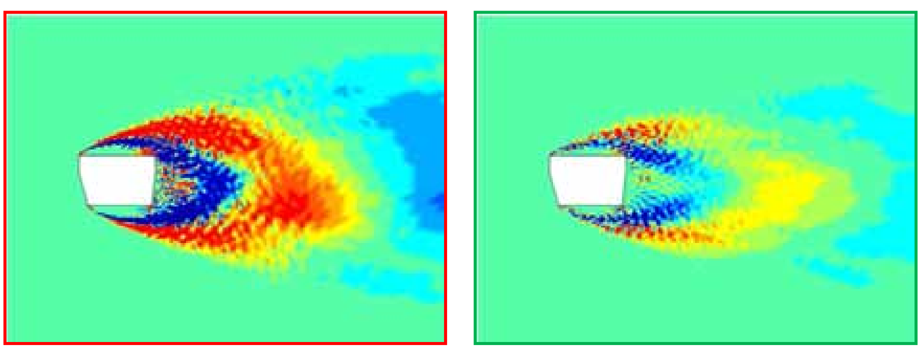
The noise generated from a pantograph, called the current collection noise, is one of the main contributors to noise along Shinkansen railway routes. Therefore, its reduction is an important research subject. The current collection noise contains two main types of noises: arcing noise and aerodynamic noise. The arcing noise is generated due to the arc discharge occurring when the pantograph is unable to maintain contact with the trolley wire, i.e. when a contact loss occurs. Measures against the arcing noise, which has very large energy, are indispensable for reducing the current collection noise. The Shinkansen lends itself to the reduction of the arcing noise because multiple pantographs can be connected to it electrically, even though it uses the AC electrification method. In addition, each Shinkansen train set operated with one pantograph uses a multi-segmented contact strip to prevent contact losses so



Measurement test of pressure distribution on pantograph-head with pressure sensitive paint in the large-scale wind tunnel



Computational fluid dynamics (CFD) has been used for research related to reduction of the aerodynamic noise of Shinkansen pantographs



Without flow-control | With flow-control

Improvement of aeroacoustic characteristics by using flow-control technique

that the arcing noise can be suppressed.

On the other hand, the aerodynamic noise is generated when unsteady motion occurs in the air while an object is moving at high speed in the air. At present, since the above-mentioned arcing noise is suppressed, the primary cause of the current collection noise is the aerodynamic noise. Reducing the aerodynamic noise is a very difficult task because its energy increases in proportion to the vehicle speed raised to the sixth to the eighth power. The fact that the Shinkansen pantograph appearance has changed greatly over time exhibits the history of various kinds of measures to reduce the aerodynamic noise as speed has increased.

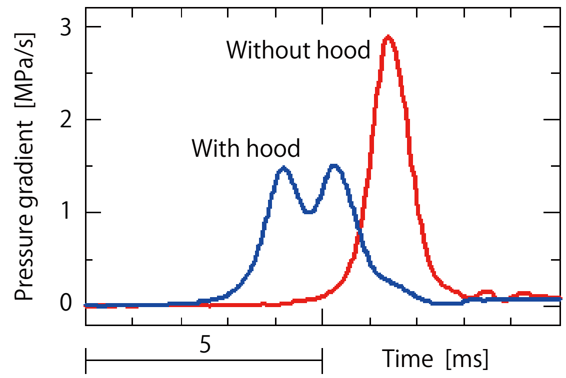
Promoting research and development aimed at reducing the aerodynamic noise needs an anechoic wind tunnel, which lowers the background noise generated and allows the aerodynamic sound from the test specimen to be measured with high accuracy. Thus, in 1996, RTRI started operation of a large scale low noise wind tunnel, which has the world's best low noise performance at the maximum wind speed of 400 km/h. The wind tunnel and various measuring techniques developed by RTRI were used extensively for the development of the Shinkansen pantograph. In addition, recently, computational fluid dynamics (CFD) has been used for research related to reduction of the aerodynamic noise of Shinkansen pantographs.

Although further reduction of the pantograph aerodynamic noise is demanded for further improvement in Shinkansen speed today, the pantograph aerodynamic noise has already been kept to a significantly low level. In addition, there is a constraint that compatibility with improved contact performance should also be achieved. Therefore, RTRI has been conducting research and development aimed at realizing more innovative pantographs by applying control techniques such as pantograph aerodynamic characteristics control and motion control (contact force control).

Mitigation Measures of Micro-pressure waves

The maximum running speed on the Shinkansen commercial lines has been increased to 320 km/h, and even faster speeds are planned. Aerodynamic phenomena become significant in at these high-speeds. In Japan, a largely mountainous country, high-speed railways have many tunnel sections. It is therefore important to consider the aerodynamic phenomena that are generated when trains enter tunnels.

One of these phenomenon is micro-



A scale model test demonstrates that the tunnel hood mitigates a spike of micro pressure wave.

pressure waves that radiate from the exit of a tunnel. As the front end of a train enters a tunnel, the air pressure in the tunnel rises, generating compression waves. The compression waves reach the other end of the tunnel and radiate out as pulsating pressure waves. These pulsating pressure waves are the micro-pressure waves. They can sometimes cause problems such as impact noise and shaking of fittings in houses near the tunnel exit.

When constructing new high-speed railways or speeding up existing systems, it is necessary to estimate the intensity of anticipated micro-pressure waves and proactively take mitigation measures. Typical solutions to micro-pressure waves include tunnel hoods that are installed on the entrance of a tunnel and shape optimization of the front end of trains. These measures are intended to reduce the pressure gradient of initial compression waves at the train entry, thereby mitigating the resulting micro-pressure waves.

RTRI has been conducting model experiments using scale models as well as numerical analysis to clarify the phenomenon of micro-pressure waves and develop mitigation measures. As part of the model experiments, a model train is entered into a model tunnel at a speed corresponding to that of a life-size train to measure the compression waveforms. RTRI mostly uses axisymmetric train and tunnel models, and conducts experiments up to a speed of 450 km/h. RTRI is now constructing a new test facility of micro pressure waves that will allow to conduct experiments up to 400 km/h with a trainset model of scale size but really shaped.

As part of its numerical analysis program, RTRI and Boston University in the U.S. developed a rapid calculation of the compression wave that uses acoustic theoretical analysis. With that computation method, results can be obtained on a personal computer faster than with the computational fluid dynamics (CFD) numerical analysis/simulation method run on a supercomputer. This makes it possible to efficiently study micro-pressure waves mitigation measures including tunnel entrance hoods and the shape optimization of the front end of trains.

Experiments using a model train and a model tunnel with the same shapes and dimensional ratios as the real versions

Conclusion

To realize further speed improvement while maintaining a good environment along the railway, the RTRI conducts various R&D activities besides those described herein. The fruits of such R&D have contributed to reducing the environmental impact not only of the Shinkansen but also of high-speed railways all over the world. In cooperation with researchers and railway operators from around the world, we would like to continue to proceed with challenging R&D toward realizing a sustainable railway.

High Speed Rail in the UK

Prof. Roderick Smith
Advanced Railway Research Centre
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Although the high-speed link with the mainland of Europe through the Channel Tunnel has been operating from London on a dedicated line since 2007 and it is now 54 years since the shinkansen opened in Japan, it is perhaps surprising that only now is a domestic high-speed rail network being realised. Why has this taken so long in a country which gave birth to the railway and for so much of its history been in the forefront of the development of the railways?

To better understand the answer to this question, it is necessary to rehearse, albeit briefly, the history of railways in the UK. From the opening of the first true inter-city railway in the world, between Liverpool to Manchester in 1830, the rail network (as distinct from a system) spread rapidly so that in the next 20 years it was possible for both passenger and goods to reach all places of consequence as well as many villages and hamlets throughout the land. The railway was built by private finance, and operated by a huge number of private companies. The system lacked coherence and there was much unnecessary duplication of routes. Natural amalgamation took place: in 1846, 70 companies controlled 66% of the railway mileage, by 1872, 16 companies had 85% and in 1907, a period known as the Edwardian zenith of the UK railway, just 13 companies controlled 88% of the routes. But by now the profitability of many parts of the railway was being called into question and public ownership was being seriously discussed. During the first world war, the railway was directly operated by the Government, was heavily used and played a vital strategic role, but was left in a relatively poor state by the end of the war, resulting in further amalgamation to just four major vertically integrated companies each covering defined geographical regions, the so-called Grouping of 1921.

The major dislocation of the thirties world depression, was rapidly followed by the second world war, during which history repeated itself, and the railway was left in very poor physical state at the cessation. The country itself was left in a weak financial position, but reflecting a mood for change and collective action, the reforming Labour Government nationalised many major industries, including the railways, from the start of 1948. Conflicting national priorities for finance meant that repair and modernisation was slow, for example steam engines were still being made for British Railways until 1960 before being finally withdrawn in 1968. Electrification was even slower: much of the railway south of London was electrified by an obsolete third-rail low voltage DC system much of which had been installed fifty years previously, well before the 25 kV AC electrification of part of the West Coast route in the sixties.

However both rail passenger and freight traffic patronage recovered until the later fifties and early sixties, when automobile ownership expanded as the car become a byword of progress and aspiration. The railways on the other hand, were viewed as yesterday's technology, usage declined, and many little used lines were closed. These closures were part of a trend which had reduced the length of route from 32 thousand km in the Edwardian heyday, to 24 thousand by 1955 and only 15 thousand in 1970. Use of other forms of public transport also declined and, for a while, the car was omnipotent. But in the 1960's great efforts were made to reverse this decline: a Railway Technical Centre was established at Derby, which employed well trained people, and which rapidly established an excellent international reputation for its work. Electrification and speed-up of routes from Manchester, Liverpool and Birmingham to London resulted in increased ridership at a time when some of the disadvantages of universal car ownership were just beginning to emerge: congestion, unreliable journey times

The Advance Passenger Train: an underfunded and over complex attempt to overcome the sinuous nature of old track by an sophisticated train.

The High Speed Train (HST): Introduced in 1976, probably the best train built in the UK and still in service on many UK inter city routes. (125 mph = 200 kph)

and parking difficulties came well before any concerns about pollution and the environment.

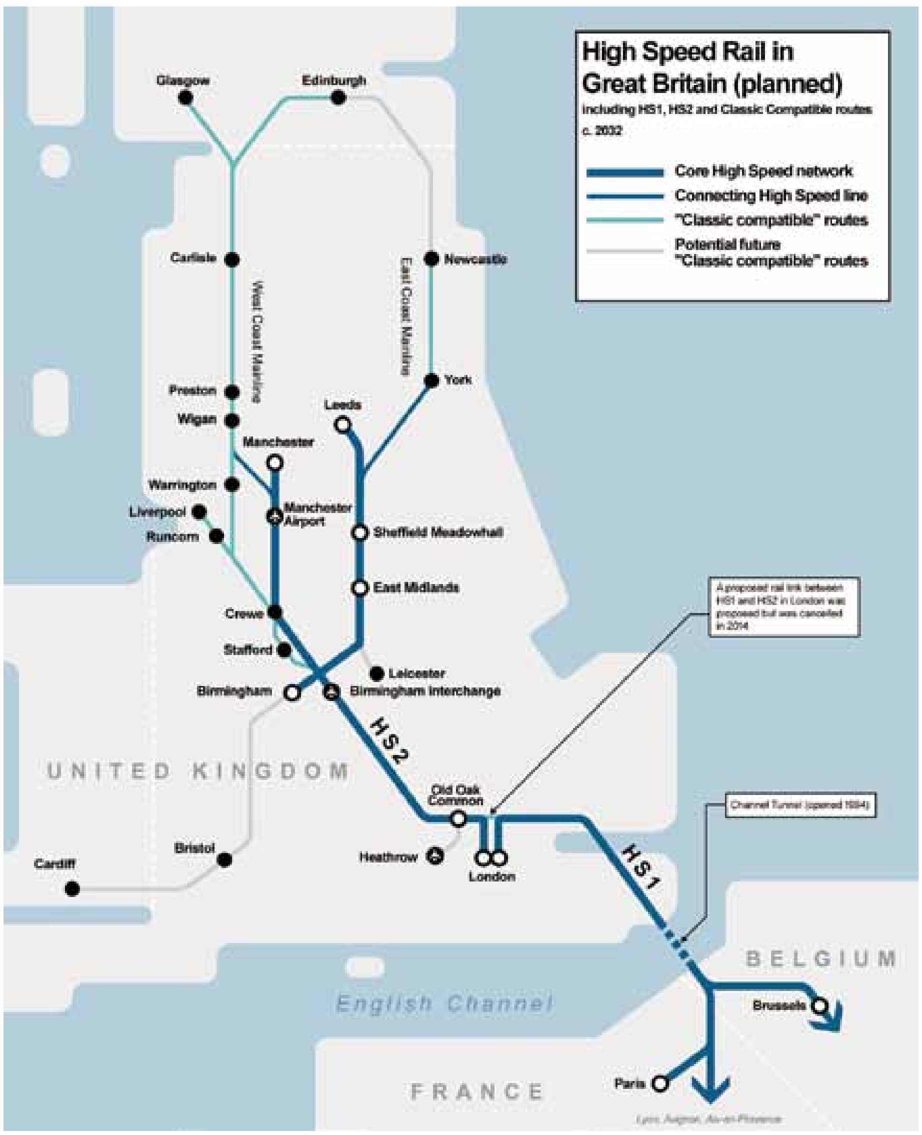
In 1969 a decision was made to improve journey times by developing a sophisticated Advanced Passenger Train (APT) which would run on existing track alignments. In retrospect, it is easy to say that, whilst major roads had been improved by motorway construction, for the railways concentration on the vehicle was not sensible, but it was, of course, much cheaper than improving and straightening existing track. Many, perhaps too many, technical innovations were incorporated in the design of APT: the need for a low un-sprung mass required the use of hydrokinetic brakes, which in turn allowed braking at a rate which conformed to the spacing of the existing lineside signalling system. Tilt was required to take curves at speeds 40% higher than existing trains, whilst light-weighting, including articulation, and high power was needed to attain the desired 50% increase in maximum speeds. The project prototype achieved a top speed of 261 kph in 1979, and a Glasgow to London (401 km) revenue journey in 4 hours and 15 minutes in 1981. However, hampered by technical niggles and chronic underfunding, the project was abandoned in the early eighties. But it spawned another train, the diesel powered Inter City 125 which benefited from much of the technical understanding from APT, but was simpler, more robust and reliable. Introduced into service in 1976, this train has been the backbone of main line express services ever since, is still going strong and is likely, now 41 years after its birth, to see further several, if not many, further years service. Initially promoted by the slogan, The Age of the Train, and much admired for its speed and ride comfort, this 200 kph train is arguably the most successful train ever produced in the UK, and is still the holder of the world diesel hauled record on 238 kph.

In the mid-nineties, the railway were privatised with the principal objective of reducing the contribution paid by the Treasury. A complicated and fragmented system emerged, in essence of operators running services on infrastructure owned and maintained by Network Rail, with vehicles owned by leasing companies. At a headline level privatisation might be considered successful: passenger km have doubled and, after a difficult start, safety is remarkably good. No passenger has been killed in a train accident for the last 11 years: the longest such period in the history of the railway. And this has happened during a period when the number of passengers and the number of journeys by rail has increased remarkably: approximately doubling since 1996, and the number of trains run has increased by nearly 30%, facts even make even more remarkable considering the much above inflation increase in fares over the same period. This increased patronage has lead to congestion at bottlenecks on the system, crowding at key stations and a woeful record of trains being cancelled and being delayed. Readers in Japan will be surprised to learn that nearly one in eight trains last year were recorded as late, even within the generous definitions of being on-time of 5 minutes for local trains and 10 minutes for long distance, and that even after this remarkable increase in passenger use, the mode share of rail is still only 9%, far below the high twenties percentage still enjoyed in Japan.

Given this situation, the Government has been persuaded that the construction of a high speed railway network could increase capacity and relieve paths on the conventional network for local traffic and freight, whilst at the same time reduce the chronic out-of-balance bias to the southern half of the country. Several years of intense debate have now concluded, Parliamentary approval has been granted and the high-speed railway is beginning to take physical shape.

Initially, a line was planned between London and Birmingham, a modern mirror of the inter-city route opened in 1838. Later a extension to the core cities of the north of England was proposed, whilst an east-west link across the country linking Liverpool, Manchester, Leeds and York is being actively promoted. It can be seen on the map that the distances involved are relatively short, in the 100 to 200 km range, thus reducing the pressure for very high operational speeds and emphasising the need for capacity.

As a long time advocate of high speed rail for the UK, the author is delighted that after such a long gestation period, physical action is now being taken to build such a network. However, my enthusiasm is tempered by several inconvenient facts, First, there have been no real efforts to win the hearts and minds of the public. In an era of constrained public finance and many worthy competing calls, as in health, education, security and housing, many people see the building of a new railway as an unnecessary luxury. The arguments about using the new railway to stimulate the economy cannot be made in a vacuum. Links with policy are weak or absent: new infrastructure is necessary but not by itself sufficient. A overall plan for the shape of eventual complete system has not emerged, and links with other transport modes, particularly airports have not been developed to best advantage. But even more concerning are the plans to operate the railway as an extension of existing arrangements.



The current plan for new high speed lines in the UK. An cross county connection from Liverpool to Manchester and Leeds is currently being mooted to create a Northern Powerhouse economic conurbation.

It has been announced that mirroring the current system of operation of the railway, the new high speed trains and infrastructure will be not be operated with vertical integration. Furthermore trains will operate off and on the ends of the newly built track onto the existing network. This has many adverse consequences. First, the poor timekeeping record of trains on the existing (classic) railway, will be inherited on the high speed lines from day one. As a result rapid turn-round times at terminus stations and more platforms and indeed more trains will be needed. At London Euston, the plan is to built 13 new platforms,, the tracks from which will reduce to two tracks at the throat of the station with a complexity of switches and crossing which can only severely hamper reliability. After more than 50 years of growth on the most densely operated line in the world, the Tokaido shinkansen, operations are from just five platforms. Over the decades, during the construction and remodelling of Tokyo Station to accommodate both the JR Central and East shinkansen lines, the station has not been closed for a single day. Already there have been weekend closures of Euston and worse is to follow.

NASA's picture of Europe by night clearly shows centres of population. Existing UK plans for new high speed lines are contained with the triangular zone. Connections with the northeast and the Edinburgh/Glasgow conurbations may be made in the future, as might a line serving London from South Wales and the West. The population density of the Low countries and the north of Italy is well illustrated as are the distributed cities of Germany and the Paris domination of France.

Because much of the rolling stock will not be captive to the new lines, it will have to be robust enough to deal with the lower track standards of the classic railway, some trains will have to be capable of operating in both electric and diesel modes, and will have to accommodate, for example, different crashworthy standards, braking distances, signalling and control system for the two types of track. They will also be constrained in width because of the restricted loading gauge of the classic system, limiting the number of seats across each carriage thus increasing energy consumption per passenger transported. All these factors increase complexity and expense while simultaneously reducing reliability and efficiency, and most certainly are not best world practice. Furthermore the weight and therefore axle loads of the duel mode vehicles will be much higher than captive stock, inevitably leading to much higher maintenance costs of the high-speed line. Clearly these fundamental weaknesses have been brought about by well meaning but flawed political decisions rather than operational and engineering experience and best practice. It is the authors hope that financial stringencies, caused by the UK decision to leave the EU, to which has been added the failure of Carillion, a major construction company which had major contacts with HS2, will lead to a rapid strategic re-evaluation to order to produce what could be a cheaper, both in capex and opex, and more efficient, reliable system.

Biographical note

Roderick Smith is Professor of Advanced Railway Engineering at imperial College London. He has served as Chief Scientific Advisor to the UK Department of Transport and as President of the Institution of Mechanical Engineers. He has visited Japan more than 70 times since his first visit in 1974 and has strong links with RTRI and the major Japanese railway companies. He is invited to lecture on railway and energy matters in countries all over the world and runs his own company consulting on railway matters.

President Dr. Kumagai and Director General Ms. Jacquot-Guimbal at signing ceremony

Agreement on Collaborative Research with IFSTTAR

The Railway Technical Research Institute and the French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR) signed an agreement on collaborative research in railway engineering at the head office of IFSTTAR in a suburb of Paris.

RTRI and IFSTTAR have an ongoing technical exchange regarding design, construction, and technical development in the field of geotechnical engineering, and they have, as a component of that initiative, also exchanged their researchers. Since it is highly likely that the research collaboration and personnel exchange will be continued in the civil engineering field, RTRI and IFSTTAR entered into this agreement in order to strengthen their collaborative relationship.

In the framework of this agreement, RTRI and IFSTTAR will implement the following research projects:

(1) Analysis of scouring at the base of river bridges and associated soil erosion
(2) Comparison of Japanese and French technical standards for base and soil structures
(3) Information sharing on the methods to analyze ground/structure dynamic interaction

Collaboration Agreements with DLR

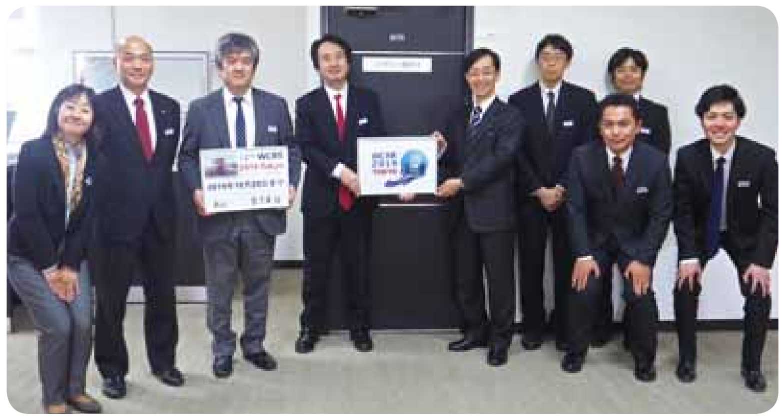
Dr. Kumagai, the President of RTRI, and Prof. Dr. Ehrenfreund, the Chair of DLR at signing ceremony

The Railway Technical Research Institute and the German Aerospace Center (DLR) concluded a Letter of Intent to build a close relationship and also signed a collaboration agreement on research in the field of large-scale 3D model experiments on micro-pressure waves.

RTRI and DLR have been sharing information on railway technologies so far. In 1997, one of RTRI's researchers stayed at DLR and conducted collaborative research on the measurement of aerodynamic noise at a wind tunnel. Since both organizations have strongly recognized the necessity to conduct collaborative research and personnel exchange, they concluded the letter of intent (LoI) to deepen their tie for the future.

Under this LoI, both parties will implement collaborative research, hold management meetings in order to further strengthen the RTRI-DLR relationship and share views for the further research collaboration including the collaborative research agreed this time.

The 12th World Congress on Railway Research (WCRR 2019)



RTRI will host *The 12th World Congress on Railway Research (WCRR 2019)* that will take place in Tokyo, Japan, from October 28 to November 1, 2019, at the Tokyo International Forum, a multi-purpose exhibition center. The theme of the congress will be "**Railway research to enhance the customer experience**".

WCRR was established for the purpose of providing an overview of the world's development of railway technologies and discussing future directions to be taken by railway operators. This is the world's largest international congress on railway research, proudly unprecedented in the sense that railway researchers and engineers gather together with managers and executives of railway operators in one congress. More than 1100 people took part in the 11th WCRR held in Milan in 2016.

Breakthroughs in research and development will be indispensable, and sometimes radical innovation to break out of the barriers of conventional railway systems might be necessary. Therefore, at WCRR 2019, we would like to provide the time and place where railway delegates from around the world are able to share their views regarding the roles that research and development are expected to play in order to further elevate the values of railways, while railway engineers and other experts are able to share information and expertise. Your participation in all possible forms will be highly appreciated in order to achieve these goals.

In the autumn of 2019, when we host WCRR, the Rugby World Cup will also come to Japan, and will be followed the next year, in 2020, by the Tokyo Olympic Games. As a result, We firmly believe that in the year 2019, you will be able to experience a highly-charged, vibrant metropolis of Tokyo.

CONGRESS OVERVIEW

Congress name:
The 12th World Congress on Railway Research (WCRR 2019)
Dates:
October 28 (Monday) to November 1 (Friday), 2019
Venue:
Tokyo International Forum (3-5-1 Marunouchi, Chiyoda-ku, Tokyo 100-0005)
https://www.t-i-forum.co.jp/en/
Host organization:
Railway Technical Research Institute (RTRI, Japan)
Organizations of the WCRR 2019 Organizing and Executive Committees:

- Union Internationale des Chemins de fer (UIC)
- Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR, U.S.A.)
- Rail Safety and Standards Board (RSSB, U.K.)
- Société Nationale des Chemins de fer Français (SNCF, France)
- Deutsche Bahn AG (DB, Germany)
- Trenitalia, Gruppo Ferrovie dello Stato Italiane (FS, Italy)
- Railway Technical Research Institute (RTRI, Japan)

ABSTRACT SUBMISSION PROCESS

Abstracts must be submitted through the official WCRR 2019 website (www.wcrr2019.org) using the on-line conference management system that can be accessed through the website.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