Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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GENERAL INFORMATION

ARTICLES

Japanese Railways and Globalization

Norio FUKUSHIRO
Executive Director

Recent years have seen an increase in the number of Japanese railway technologies exported overseas. Issues such as the technologies provided for construction of the Taiwan High Speed Rail and the export of high-speed trains to Asian and European countries have been much talked about in Japan. In urban railways, exports have grown solidly, while a significant amount of rolling stock is now produced overseas using technology developed in Japan.

Very few trains in use in Japan, however, are manufactured by overseas companies, the only real example being the Hiroshima Electric Railway low-floor trams from Germany. Why is it that trains from overseas are not used in Japan?

Japan National Railways (JNR) held almost all relevant technologies in Japan, as JNR maintained and operated railways throughout Japan for many decades. (They were operated by Japanese Government Railways before World War II.) As a result, the roles of the operating company and manufacturers became well defined—JNR (the operating company) would determine detailed specifications of rolling stock, equipment and facilities while manufacturers would deliver products according to such specifications.

The roles of operating companies and manufacturers are somewhat different overseas. As in many cases individual train services cover a number of countries and are operated by several different companies, manufacturers have played an active part in development of rolling stock and other facilities. It is likely that this difference is the main reason rolling stock and technologies from overseas have not been used in Japan to a significant extent.

However, with economic globalization, further growth will be seen in import and export of railway technologies and joint development between Japan and overseas. With such trends, international standards will become increasingly important as keys to establishing a fair international business market.

RTRI should therefore devote sufficient attention to international standards when determining the direction and details of future research.

A Report on International Standards Meetings Recently Held in Japan
—JISC-CENELEC Information Exchange Meeting and LIM Kyoto Meeting—

Hiroyuki NOZAWA
Manager, International Standards Center, International Affairs Division

The RTRI International Standards Center acts as the Japanese National Committee for the IEC TC9, a technical committee on Electrical Equipment and Systems for Railways established under the International Electrotechnical Commission (IEC). Fig. 1 shows the system in place in Japan for the deliberation of issues. I would like to report on several international meetings recently held in Japan on international standards, for which the RTRI International Standards Center acted as secretariat.

The Japanese Industrial Standards Committee (JISC) and the European Committee for Electrotechnical Standardization (CENELEC) held their 12th Information Exchange Meeting in Tokyo from Oct. 1 to 3, 2007. A working group on railways was established at the meeting, at which presentations were made on recent progress in the development of standards in Japan and Europe and information on new railway technologies was exchanged. Agreement was reached to establish a similar working group on railways at the next JISC-CENELEC Information Exchange Meeting. A tour of RTRI facilities was held on Oct. 2, and was very popular with participants (Fig. 2).

An IEC TC9 Automated Urban Guided Transport (AUGT) Ad Hoc Group meeting was held at the Nippon Sharyo Ltd. Headquarters in Nagoya from Sept. 19 to 21 last year. AUGT standards specify safety requirements for the driverless operation of new transit systems. This is the second time that an AUGT meeting has been held in Japan, the last time being in 2002.

A visit to the Linimo linear motor train system operated by Aichi Rapid Transit Co., Ltd., was arranged for Sept. 21. After watching a video presentation with commentary in English, participants visited the operation control room and train depot.

An IEC TC9 PT62520 meeting was held in Kyoto from Jan. 22 to 24 this year. Under PT62520, efforts are being made to create international standards for car-mounted primary linear induction motors (LIM), which are chiefly used in subway systems. A new work item proposal from Japan was adopted for such standards and progress has already been made to draw them up.

The PT62520 project is headed by Takafumi Koseki, Associate Professor at the University of Tokyo. At the meeting in Kyoto, the first time that the project team had gathered, participants held discussions on a working draft proposal (Fig. 3).

On Jan. 24, participants toured the Osaka Municipal Transportation Bureau's linear motor subway depot, and both Japanese and overseas participants were very interested.

Such international conferences held in Japan make far-reaching contributions to efforts towards standardization. The RTRI will continue to offer all the support it can in these endeavors.

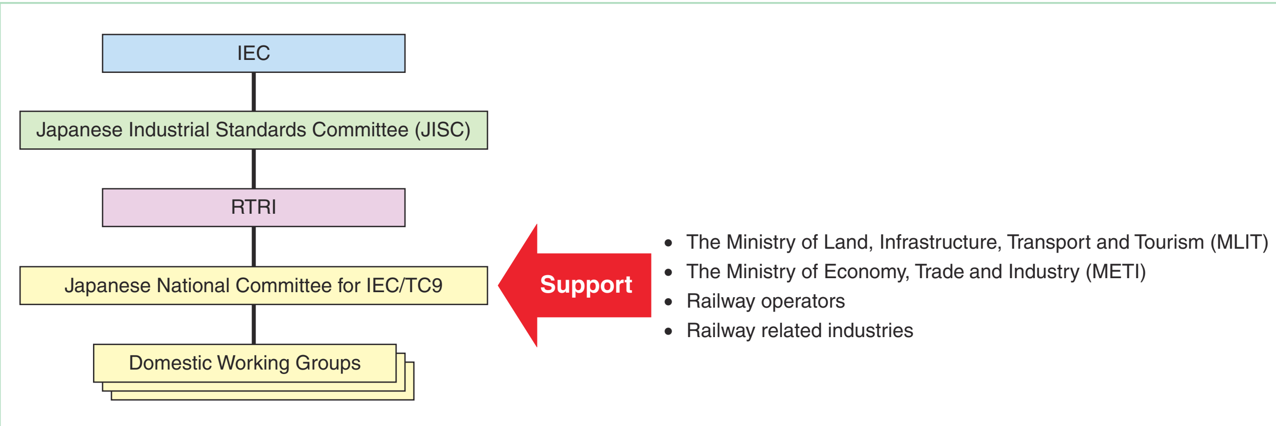


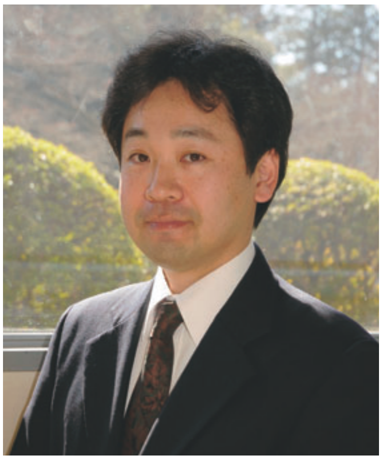
Fig. 1 System in place in Japan for the deliberation of issues

Fig. 2 Meeting participants at RTRI facility

Fig. 3 First PT62520 project team discussion meeting

Development of High-Temperature Superconductor Magnets Capable of Generating a High Magnetic Field

Masaru TOMITA
Senior Researcher, Applied Superconductivity, Materials Technology Division



Until now, the problems of mechanical strength and thermal stability have created a bottleneck for the practical application of high-temperature superconductor bulk magnets. These problems have been resolved using new technology, and as a result, a high-temperature superconductor has been successfully made to generate a magnetic field of 17.24 tesla, the highest level achieved in such a material (Fig. 1). This research was published in the British scientific journal *Nature* 421, 517-520 (see http://www.nature.com/nature/journal/v421/n6922/full/nature01350.html), and has attracted worldwide attention.

As the intensity of the magnetic field generated in a bulk superconductor increases, the superconductor itself is subjected to an increasing electromagnetic force that imposes a growing load on its material strength. This is a serious problem, and the intensity of the magnetic field generated can even rise as high as the strength limit. Bulk superconductors have a large thermal expansion coefficient together with low thermal conductivity. The material they are composed of is also highly anisotropic, which makes it fracture easily. Consequently, a tensile stress is generated between the interior and exterior of the sample during the cooling phase of fabrication. The result is that microcracking occurs. These cracks had been thought to reduce the strength of the superconductor, and they did not diverge from the estimated range.

A method was devised to impregnate bulk superconductors with epoxy resin in a vacuum, and it has been confirmed to be capable of dramatically improving their mechanical properties. Thanks to this discovery, the mechanical strength has been enhanced dramatically and the generated magnetic field has also been upgraded. When an attempt was made to trap an extremely high-intensity magnetic field, however, it was found that the material would break down at about 14 tesla, regardless of the increased mechanical strength. Testing was done to measure the heat generated in the interior of the superconductor in conjunction with a particular phenomenon known as flux jump that occurs with superconductivity. It was demonstrated that the generation of this heat causes bulk superconductors to become normal conductors that are unable to trap a high magnetic field. Attempts to make the bulk superconductor trap a field cause quantized flux to penetrate from the exterior to the interior of the superconductor, and the movement of this flux necessarily results in the generation of heat. There is no problem if this heat can be quickly removed by an exterior coolant. If the heat continues to be generated, however, the temperature will rise locally. The result is that the rise in temperature is accompanied by a sudden drop in superconductivity, and the large electromagnetic force caused by sudden change in the magnetic field eventually destroys the magnet itself. This thermal instability of bulk superconductors is due to their low thermal conductivity. Poor heat transfer causes heat to pool inside the superconductor, the superconductivity breaks down, and the superconductor becomes unable to trap a magnetic field. Therefore a hole was drilled at the center of a bulk superconductor that had been previously impregnated with resin, and metallic aluminum, which has high thermal conductivity, was introduced into the hole. The superconductor was then impregnated with an alloy with a low melting point (Bi-Pb-Sn-Cd: melting point 100–105°C) in order to conduct heat and raise the thermal conductivity (Fig. 2). The low-melting-point alloy infiltrated the cracks inside the superconductor and yielded a very efficient heat transfer characteristic. Allowing heat to escape from the interior limits the pooling of heat and realizes thermal stability in the bulk superconductor. In a synergistic effect with the resin impregnation, which improves the strength, the high-temperature superconductor was able to generate an extremely high magnetic field exceeding 17 tesla. This technique of resin impregnation and metal impregnation of bulk superconductors has been highlighted for potentially broad practical application as a rational method for increasing strength and thermal stability in order to improve magnetic field generation. The technology is being used in Japan and other countries in the development of such applications as current leads for use in Maglev, flywheels (power storage), nuclear magnetic resonance (NMR), magnetic resonance imaging (MRI), superconducting motors, magnetic separators, and permanent current switches (PCS).

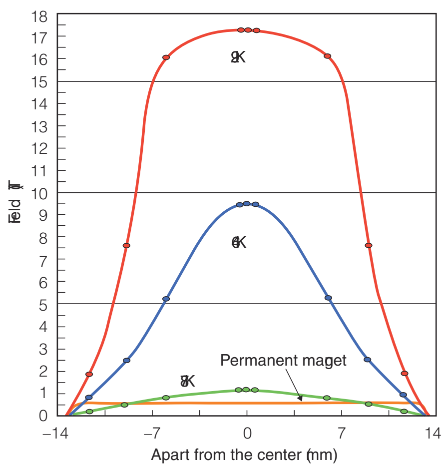


Fig. 1 The field distribution trapped by bulk superconductors with impregnation technique

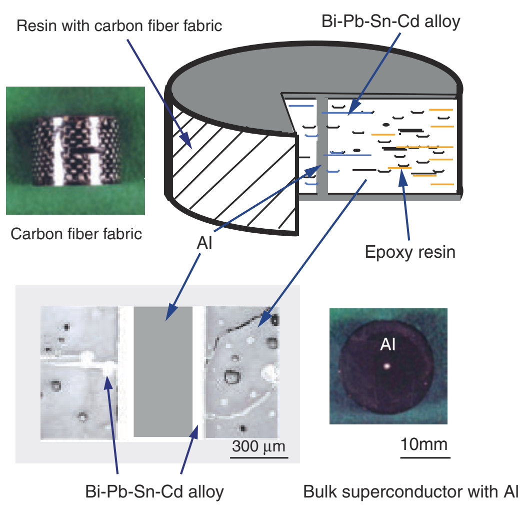


Fig. 2 Structure and optical micrographs of bulk superconductors for high trapped-field

U-Doppler, a Non-contact Vibration Measuring System for Diagnosis of Railway Structures

Fumiaki UEHAN
Senior Researcher, Structural Mechanics, Railway Dynamics Division

The development of a simple and accurate method of monitoring railway structures, including viaducts, bridges and embankments, has long been sought. Such a method would allow large numbers of civil engineering structures to be more efficiently maintained and would make it easier to detect deformations in a timely manner following a natural disaster. For this reason, inspection techniques using vibration measurement of structure have been developed in the field of health monitoring of railway structures. The inspection techniques make use of the vibration characteristics of structures, such as maximum response, natural frequency and mode shape as the index of the soundness of structures. The vibration induced by sources such as passing trains, shock from weight impact and microtremors, is used in order to obtain the indices for inspection. When measuring vibrations using this method, the installation and removal of sensors is extremely time-consuming and, in many cases, work must be performed in dangerous locations such as high places or near railway tracks or structures damaged by natural disasters.

The author therefore developed the U-Doppler (Fig. 1, Table 1), a long-distance non-contact vibration measuring system for the diagnosis of railway structures that offers enhanced safety and efficiency by implementing various improvements to the Laser Doppler Velocimeter (LDV) for use in the field. The U-Doppler sensor is placed on a tripod near the structure to be measured and the laser is irradiated to the structure (Fig. 2). The vibration (velocity) of the structure can be measured using this approach in the same way as when a sensor is fitted to the structure. It is possible to measure vibrations of a variety of magnitudes from several dozen meters away, from relatively large vibrations of structures from a passing train to microtremors—microscopic vibrations under normal conditions due to natural and artificial sources, such as tidal waves, winds, traffic noise, and industrial vibration. U-Doppler saves considerable time, as it does not require sensors to be installed or removed, and eliminates the risk associated with having to work in dangerous locations.

The main technical feature of the U-Doppler is the compensation function using the built-in sensor. Because the LDV is a device that detects the relative velocity between the LDV itself and the object being measured, accuracy decreases when it is used to measure structural vibrations outdoors, as a result of the vibration of the LDV itself caused by various ground vibrations and/or the wind. In addition to the LDV optical sensor, the sensor unit of the U-Doppler incorporates a contact vibrometer with the same sensitivity and phase properties as the optical sensor. The influence of U-Doppler sensor vibration is removed by using the time-history data recorded by the installed vibrometer (Fig. 3 (a)). Also, when performing measurements on civil engineering structures, in many cases, the direction of the structural vibrations and the optical axis of the irradiation laser do not correspond (Fig. 3 (b)), which means the amplitude of vibration of the object is not measured correctly. The U-Doppler has thus been fitted with an internal sensor to measure the inclination of the unit and automatically adjust the amplitude measurement data as necessary.

The U-Doppler data recorder displays a variety of data in real time (Fig. 4), including velocity before compensation, vibration of the sensor unit, velocity after compensation, spectra for all data and the sensor inclination. Analysis of data, including spectrum analysis, differentiation and integration and filter processing, can be performed at the measurement site.

The U-Doppler is already being used to estimate the natural frequency of viaducts and bridge piers and to measure the deflection of bridge beams, and further use is planned.

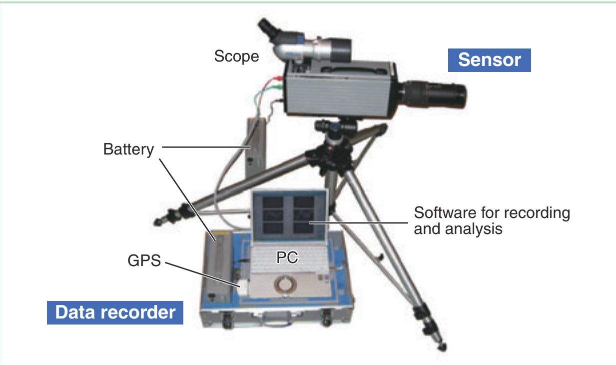


Fig. 1 Non-contact vibration measuring system "U-Doppler"

Table. 1 Specifications of sensor unit

Dimensions and weight	113 (W) × 141 (H) × 351 (D) mm, 5.5 kg
Power supply	Battery (operation time: 8 hours) or AC adapter
Laser protection class	Eye-safe Class II visible He-Ne gas laser
Velocity range	0.2 μm/s to 100 mm/s
Frequency range	DC to 600 Hz
Working distance	1.0 to 100 m (surface dependent)

Fig. 2 Measurement of bridge pier vibration by U-Doppler

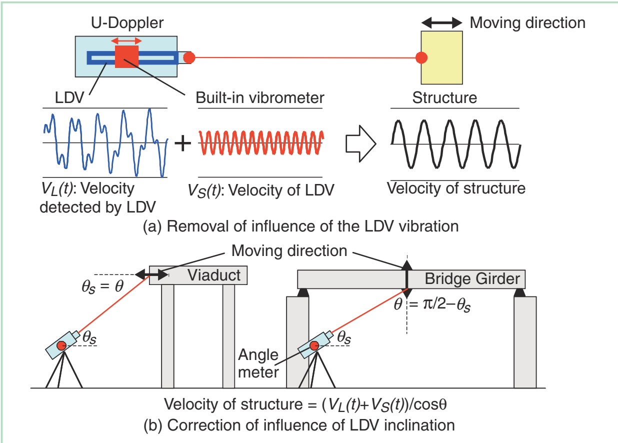


Fig. 3 Correction of detected velocity by using built-in sensors

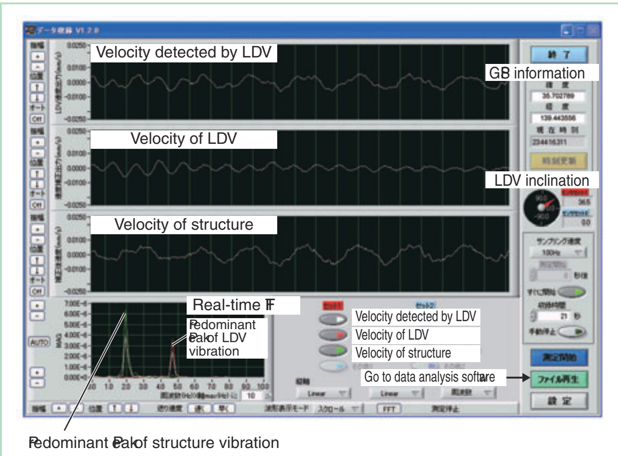


Fig. 4 Display of data recording software

Development of a Method to Predict Passenger Numbers upon Resumption of Train Service

Masai MUTO
Senior Researcher, Laboratory Head, Transport Planning, Transport Information Technology Division

The huge number of people carried by railway systems in major Japanese cities means that trains operate at extremely frequent intervals. Train drivers and conductors are constantly working to keep trains running exactly on schedule—measured by the second. Japanese trains are famous throughout the world for their punctuality. Nevertheless, when an accident causes an interruption to service, traffic controllers must reschedule trains to resume normal operations as soon as possible. The aim of this study is to obtain information on the number of trains required when service is resumed from an estimation of passenger numbers, so that better methods of train rescheduling can be formulated.

Faced with a sudden interruption to train service, passengers must decide what course of action to take. They can wait until service on the line resumes, use the extensive rail network to take another, less direct route to their destination, use an alternative means of transport such as bus or taxi or cancel their travel plans altogether. An Internet questionnaire survey was conducted on rail users that experienced such a disruption to service. To understand in detail the reasons behind passengers' decisions regarding the best course of action to take, it is necessary to ask them about the experience while it is still fresh in their minds. Passengers were therefore asked to respond on the day of the disruption. Analysis of the survey results revealed the following.

(a) The vast majority of passengers opted to continue their journey by rail—over 90% chose to wait for service to resume or use an alternative route (Fig. 1).

(b) Over 85% of such passengers made their own prediction with regard to the time it would take for service to resume (Fig. 2).

A model was constructed for the two main actions taken—using an alternative route and waiting for service to resume. The disaggregate logit model, widely employed in transport demand forecasting, was used. The explanatory variables were given the following properties.

(a) The time required to reach the destination in the case of waiting for service to resume is the total of the journey time including transfers and the time waiting for service resumption (as provided by station staff or predicted by the passenger).

(b) The threshold is introduced into difference in utility between taking an alternative route and waiting for service resumption using the inverse of the waiting time.

Using this model, a case study simulation was performed based on the assumption of a sudden interruption to rail service on a certain line (Fig. 3). This model was used to calculate the probability that passengers arriving at Station X would choose to travel using an alternative route at 1-minute intervals following the interruption (Fig. 4). This enables the number of passengers waiting at Station X for service resumption to be calculated.

The reproducibility of the model was verified by comparing the actual decrease in customer numbers as a result of disruption to service (using origin/destination data from automatic ticket gates) and the decrease calculated using the model. Commercial use of this method of predicting passenger numbers is now anticipated as its validity has been confirmed.

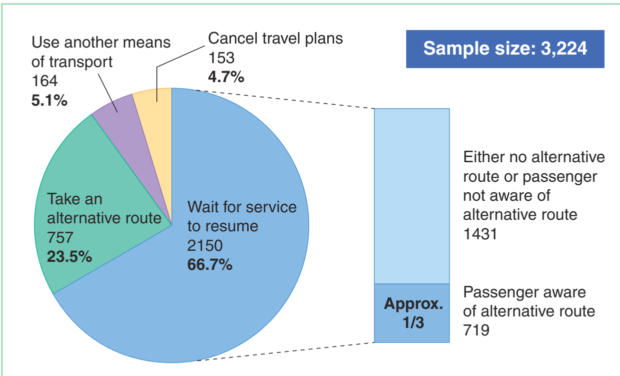


Fig. 1 Decisions taken by passengers

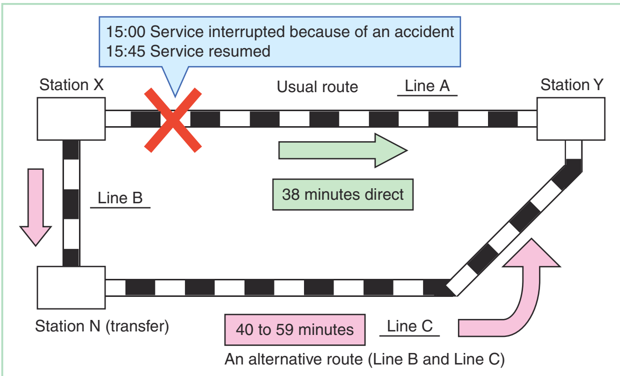


Fig. 3 Case study railway line

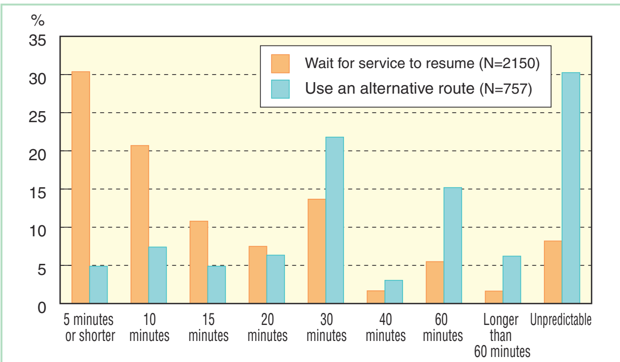


Fig. 2 Action taken by passengers and predicted time for service to resume

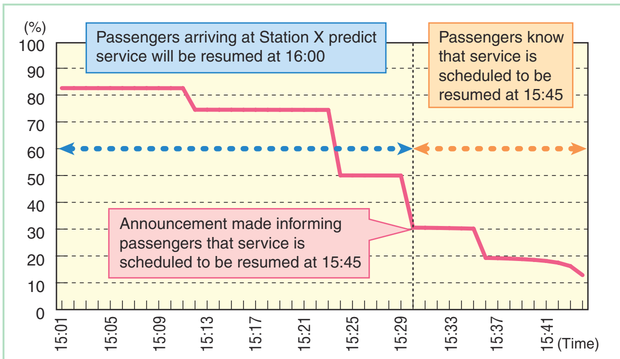


Fig. 4 Percentage of passengers choosing to take an alternative route as calculated using the model

Computational Simulation Method of Evaluating Aerodynamic Sound Sources

Takehisa TAKAISHI
Assistant Senior Researcher, Noise Analysis, Environmental Engineering Division

Noise generated aerodynamically has become the dominant noise generated by today's high-speed trains, which run at a maximum speed of 300 km/h (190 mile/h) in Japan. The aerodynamic noise is produced mainly by projecting devices, such as pantographs and cable heads on the roof, gaps between cars, and cavities at the bogie sections. This noise is proportional to the 6th-8th power of the wind (vehicle) speed, and at high speeds it exceeds other noises, such as the rolling noise from wheels and rails, which is normally proportional to the 3rd power of the vehicle speed. Since the Environmental Quality Standards established by the Japanese government stipulate that the peak noise level shall not exceed 75 dB(A) at trackside, it is crucial to reduce the aerodynamic noise produced by trains.

Although experiments in a low-noise wind tunnel are an effective way of examining preventative measures against aeroacoustic problems, it is difficult to determine experimentally the detailed relationship between an unsteady flow motion and sources of aerodynamic noise. Many previous numerical simulations calculated the pressure fluctuations at the body surface and then estimated the acoustic pressure fluctuations in the far field using Curle's equation. However, they could not directly identify the structure of sound sources in the flow, and the relationship between flow and radiated sound was unclear.

Then we developed a numerical method based on the theory of vortex sound, which suggests that the unsteady motion of vortices produces aerodynamic sound. We combined the calculation of unsteady flow and the evaluation of acoustical performance numerically. First, the unsteady flow around the body is obtained using the large eddy simulation (LES) technique, which solves the spatially filtered equations of continuity and momentum for incompressible flow. Second, the acoustical performance by the presence of the body is estimated by solving a Green's function adapted to the body shape. Finally, by coupling the instantaneous flow properties with the Green's function, the distribution of aerodynamic sound sources around the body is obtained. We also proposed a new idea that avoids the sudden termination of vortices at the outer boundary of a finite computational domain and extracts the net contribution from so-called dipole sound sources.

Fig. 1 shows a numerical result of the distribution of aerodynamic noise sources around the pantograph horn, which are installed at both side-ends of a pantograph head in order to ensure movement onto the contact strip of out-of-running wires. Periodic holes in the cylindrical horns were already known to reduce the noise level, but the detailed mechanism of noise reduction was not clear. The result proves that intermittent flow through holes suppresses the strength of dipole sound sources at the shear layer and collapses the large two-dimensional structure of sound sources in the spanwise direction.

Fig. 2 shows another result around a pantograph head. Strong vortices are shed from each corner periodically, and these create an unsteady force that acts on the pantograph head. Strong noise sources are formed in regions where the variation of flow over time is great. Such findings will set important guidelines for improving shapes for noise reduction and adequate contact force.

The new method proposed here is capable of estimating the acoustic pressure fluctuation in the far field using detailed information about the structure of sound sources in the flow, and is applicable to other aerodynamic noise generated by various parts of the train. Using this method, the process of developing a new generation of high-speed trains is expected to be shortened.

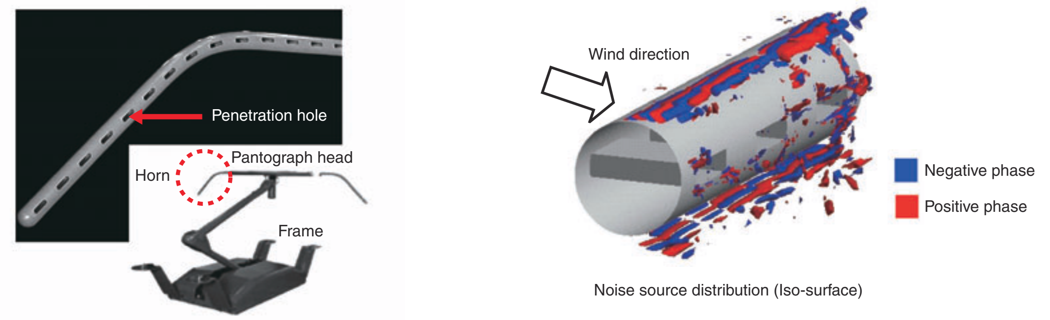


Fig. 1 Distribution of aerodynamic noise sources around the pantograph horn

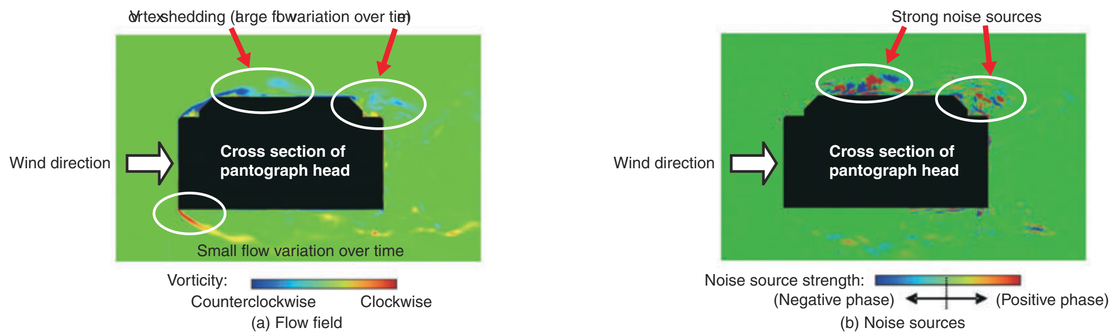


Fig. 2 Flow field and aerodynamic noise sources around the pantograph head