Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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President's Inaugural Address

Hisashi TARUMI
President

I assumed office as the President of the Railway Technical Research Institute (RTRI) in April 2009, succeeding Dr. Akita. After joining the RTRI when it formed part of Japanese National Railways (JNR) 39 years ago, I experienced a number of different positions including several at other organizations within JNR. At the time of the privatization and division of JNR, I was involved with planning the re-organization of the RTRI as an independent entity. For more than 20 years, the RTRI has been steadily attaining success in the field of R&D, especially in the development of railways for higher speeds, in the prevention of natural disasters, including earthquakes, and in the improvement of safety and convenience of travel, thereby making a significant contribution to railway operators as well as to Japanese society. The responsibilities now assigned to me are to follow through the current master plan, which is now in its final fiscal year, to prepare a new master plan for the coming years, and to promote preparations to cope with the reorganization of the public-interest corporation system undertaken by the Japanese government. Regarding the current master plan, the accomplishment of research projects that require comparatively long research periods is important. These include the design and application of a new signalling system, development of an evaluation method for vehicles' dynamic characteristics by using a hybrid simulator (HILS), evaluation of seismic performance and establishment of disaster-prevention countermeasures for existing railway facilities. In preparing a new master plan, on the other hand, it is necessary for the RTRI to establish R&D plans which will enable railways to play a greater role in sustainable development not only using our past experience but also taking fresh ideas and looking at the railway from a different angle. We shall also need to introduce research results and techniques covering non-railway fields as well. I will endeavour to accelerate the integration of accumulated knowledge on fundamental technologies and focus more on basic research. The RTRI is now preparing documents and materials required for the renovation of the public-interest corporation system.

Although it is still not known how this issue will develop in the future, I will do my utmost to reinforce the already-established close relationship with the railway operators.

The various industries need to respond seriously to the global economic slowdown triggered by financial crises, the reduction of greenhouse gases, and problems of resources and energy. Expectations for railways are constantly rising and in particular, there is really no end to the topics of railway enhancement and revitalization in overseas countries. In order to efficiently promote R&D capable of contributing to railway businesses while solving various problems, it is essential to enhance co-operation with related research organizations, in this country and overseas. I sincerely request you to positively extend your co-operation and exchange information with the RTRI. This Newsletter has been issued since 2003, as proposed by Dr. Hiroyuki Sakai, International Affairs Division, when I was Executive Director, International Affairs, so as to quickly publicize research outcomes abroad. I thank you for your understanding and co-operation.

Development of a Large Two-Dimensional Shaking Test Facility to Determine How Railway Equipments and Structures are Damaged or Destroyed during an Earthquake

Masayuki KODA
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The Railway Technical Research Institute (RTRI) has introduced an embankment shaking test facility as part of a research programme to improve the resistance of embankments to earthquakes. This research applies specifically to embankments on soft ground that were seriously damaged by the Tokachi Offshore Earthquake in May 1968. The series of research works have led to a number of achievements in the development of quakproof embankments and similar structures thanks to shaking tests conducted on full-scale model embankments.

Railway structures were badly damaged by the earthquake that occurred in the southern part of Hyogo Prefecture in January 1995. On another occasion a Shinkansen train running in commercial service was derailed when an earthquake struck the Chuetsu District, Niigata Prefecture, in October 2004. This was the first accident of its kind to occur in the history of Shinkansen passenger services. As a result, railway engineers and researchers are now urgently required to find out the behaviour of track, rolling stock and infrastructure when an earthquake occurs and to put in place countermeasures to prevent derailments.

In order to find out the behaviour of the railway structures, track and rolling stock that are damaged or destroyed by strong seismic movements during an earthquake, RTRI decided to build and install a large two-dimensional shaking test facility on its own premises. This enables simulation of actual earthquake motions with a seismic intensity of 7; the facility also permits the bogies of rolling stock to be shaken. As analysis, measurement and control technologies have progressed dramatically in recent years, real-time hybrid tests that combine "dynamic analysis" and "shaking tests" are now being used.

In particular, finding out the dynamic interaction of structures with track and rolling stock is an extremely important subject for railways. In order to satisfy this requirement, we considered it necessary to have our sights set on establishing and developing a system capable of performing tests to verify the ability of structures to withstand earthquakes at extremely low cost. The system also had to be able to evaluate the relationship between the response of the entire system and local damage by linking dynamic tests using full-size or small scale-ratio models with multi-freedom dynamic analysis performed using computers, on a real-time basis. Consequently, the shaking test facility that has been introduced has main characteristics that respond to these requirements, as shown below.

(1) The largest displacement amplitude of the shaking table is ±1,000 mm. "*Excitation with large displacement amplitude*"

(2) Controlling excitation makes use of a real-time reaction force compensation control system. "*Excitation with high precision*"

(3) The foundation of the shaking test facility makes use of a floating structure. "*This is because of the need to avoid disturbing the environment in the surrounding area*"

Table 1 shows the basic specifications of the shaking test facility, and Figs. 1 and 2 show its structure and appearance.

Having started designing and constructing the shaking test facility in September 2006, RTRI finished the construction work after two years, and the test facility was completed at the end of October 2008. RTRI began full-scale operations with the facility in fiscal 2009. In order to determine how railway equipments and structures are damaged or destroyed during an earthquake, RTRI is going to perform shaking tests using seismic motions. This shaking test facility was designed and manufactured with financial support from the Ministry of Land, Infrastructure, Transport and Tourism.

Table 1 Basic specifications of the shaking test facility

Excitation method	Hydraulic servo type
Dimensions of shaking table	7m (X-axis) ×5m (Y-axis)
Maximum surcharge load	50 tons
Direction of excitation	Lateral 2 axes (X- and Y-axes)
Maximum displacement (acceleration at the maximum displacement)	X-axis : ±1.0m (0.25G) Y-axis : ±0.25m (0.23G)
Maximum speed	X-axis : ±1.5m/sec Y-axis : ±0.75 m/sec
Maximum acceleration	X-axis : ±1.0G Y-axis : ±2.0G
Excitation frequency	0.1〜20Hz
Excitation pattern	Seismic wave excitation, sine wave excitation
Excitation control method	Acceleration control, displacement control Reaction force compensation control

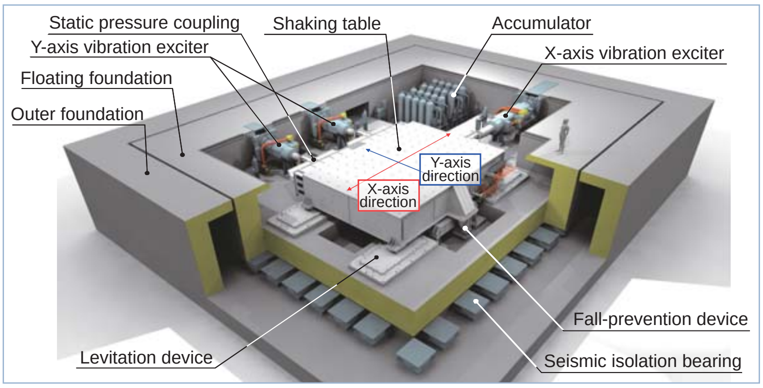

Fig. 1 Structure of the shaking test facility

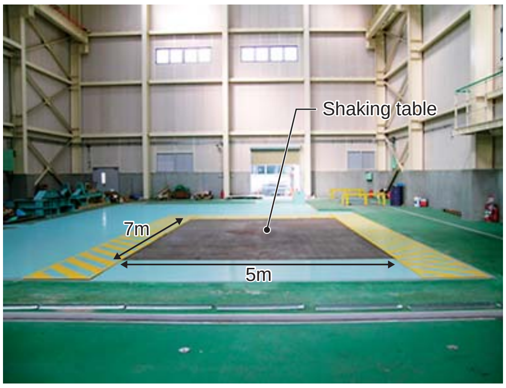

Fig. 2 An appearance of the shaking test facility

The 10th International Workshop on Railway Noise

Tatsuo MAEDA
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The 10th International Workshop on Railway Noise (IWRN10) will be held on October 18-22, 2010 in Nagahama, Japan.

The IWRN is a unique international workshop that started in Derby, UK, in 1976 specifically for the discussion of railway noise and vibration among world experts and practical engineers. Since then, it has grown into a gathering of over 100 experts in the field of railway noise and vibration. The last Workshop was held in Feldafing, Germany, in 2007.

The RTRI is delighted to have the opportunity to act as organizer of the 10th Workshop - the first to be held in Asia. The Japanese Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of the Environment will also support the Workshop.

The venue for the Workshop is the Nagahama Royal Hotel, located on the eastern side of Lake Biwa, Japan's largest lake.

Continuing the tradition of previous IWRNs, this workshop will provide a unique forum for researchers and experts in railway noise and vibration. Both the time schedule and the venue of the workshop are intended to enhance a lively exchange of experience and viewpoints amongst the world's leading researchers and experts. To ensure comprehensive discussion of topics among all the participants, there will be no parallel sessions in IWRN10.

The Workshop will feature oral and poster presentations. The International Committee seeks excellent original papers relating to railway noise and vibration, such as noise sources (wheel/rail noise, aerodynamic noise, structure-borne noise and micro-pressure wave), prediction tools and theoretical models, measurement methods, new noise reduction technologies, and ground-borne noise and vibration. Papers on legal regulations and perception are also welcomed. Oral and poster presentations will be held from the morning of October 19 until midday on October 22.

A complimentary technical tour to the RTRI's Wind Tunnel Technical Center will take place in the afternoon of October 22.

Besides workshop proceedings, selected papers will be published as a dedicated issue of the Notes of Numerical Fluid Mechanics and Multidisciplinary Design (Springer), which will be sent to all participants of the Workshop.

The following are important dates for authors:

December 25, 2009:	Deadline for two-page summary.
February 26, 2010:	Notification of acceptance.
May 28, 2010:	Deadline for full paper.

For further information on the IWRN10, please visit our website (http://www.rtri.or.jp/IWRN10) or contact us by e-mail (iwrn10@rtri.or.jp).

Wind Tunnel Technical Center

The 8th China-Korea-Japan Railway Research Technical Meeting

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Since 2001, the China-Korea-Japan Railway Research Technical Meeting has been held annually, rotating between CARS*, KRRI** and RTRI. Each occasion has taken the form of a seminar where joint research was discussed by the three organizations.

On November 19 to 21, 2008, RTRI hosted the 8th meeting. Eight members from China, led by Mr. Kang, Executive Vice President of CARS, and 11 members from Korea, led by Dr. Bang, Vice President of KRRI, visited RTRI. From RTRI, four researchers in charge of joint research, members from the R&D Promotion Division and the staff of the International Affairs Division, headed by Dr. Kumagai, Executive Director of RTRI, participated in the meeting.

On November 19, the first day of the meeting, the participants had a study tour of RTRI's new test facilities in the morning and held meetings of joint researchers on relevant research themes in the afternoon. In parallel, the leaders of the three research organizations had a meeting to exchange frank opinions on the status of their railways and their future vision on railway research institutes.

During the morning of November 20, the three leaders presented keynote addresses, and a researcher from RTRI made a special presentation on the technology of tilting trains. In the afternoon, participants made presentations on nine research themes including those on a monitoring system for railway infrastructure and life cycle assessment for railway system contributed by RTRI researchers. After the end of the seminar we finalized the minutes of the meeting on the promotion of tripartite joint research projects and research themes adopted for the projects. The minutes were then signed by the three leaders.

On November 21, the 8th China-Korea-Japan Railway Research Technical Meeting was successfully closed after the delegations made a technical visit to the Railway Museum in Saitama.

* CARS: China Academy of Railway Sciences
** KRRI: Korea Railroad Research Institute

Structural Improvement of Existing Steel Bridges by Combining the Steel Girders with Concrete Decks

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More than half of the steel railway bridges in Japan have been in service beyond their designed lifetime. Some of them need to be replaced mainly because corrosion has caused degradation of their load-carrying capacity. However, replacement is an expensive option which is also costly in terms of time as train operations have to be halted.

As one method of improving the load-carrying capacity of the bridges without replacing them, we proposed the idea of combining the steel girders with a concrete deck, as shown in Fig.1. This method changes the structural system of a steel girder into a composite girder and increases its load-carrying capacity. In addition, this method also helps to mitigate the accumulation of fatigue damage by reducing stress in the girders and to reduce noise caused by vibration of the bridge members.

To implement this technology, an increase of the dead load and the method of deck installation needed to be examined. Focusing on the dead load, the range of application for this method was estimated. As for the deck installation, the key points would be the time required for installation and connection between the girders and the decks. Then we proposed a method requiring only a short time for installation using precast-concrete decks and we evaluated the resistance of the girder-deck connection by means of loading tests.

When the concrete deck is installed on the existing bridge, an increased dead load acts directly on the bridge supports. Then we calculated the bearing stress of the concrete of the supports, before and after the deck was installed. The calculation models are deck girders and through girders with a simple span and a single track. Figure 2 shows the results of the calculation. In the bridges with span widths of more than 40 m, the bearing stress of the concrete of the supports exceeds the allowable stress. Thus, we found that this method could be applied to bridges with span widths of less than 40 m.

When installing concrete decks on steel girders, we had to consider the time constraint. On lines with heavy traffic, halting train operations is not acceptable and the installation has to be finished within a specified time slot during the night work. So we proposed a method of installation using a precast-concrete deck. In this method, decks can be installed during a short-time possession at a worksite. Furthermore, installing precast concrete decks on longer bridges can be carried out by splitting the workload into several short night-time possessions for each precast deck (Fig. 3).

Focusing on the installation method with precast concrete decks, it is necessary to examine the resistance of the connection between the girders and the decks. For this reason, we proposed a connection system of steel girders and precast-concrete deck using steel fasteners and mortar filler (Fig.4). The strength of the connections was then evaluated by loading tests. Figure 5 shows the loading test of the connection by filler mortar. As a result, it was found that the connection has high shear resistance because of rivet heads on the surface of the steel girders (Table 1). Loading tests of the connection using fasteners were also carried out, and it was found that the connection has sufficient resistance against vertical and transverse forces.

In this study, a method of structural improvement of existing railway steel bridges by combining the steel girders with concrete decks was proposed. Then the applicability of the method was evaluated through design calculations and loading tests. We found that the deck installation method using precast concrete decks can be used with short-time possessions during the night work and that the girder-deck connection has sufficient strength to withstand the forces applied by live loads. We are planning to develop this technology so that it can be applied to actual structures.

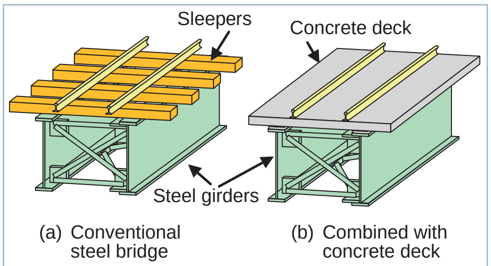

Fig. 1 Combining the steel girders with a concrete deck

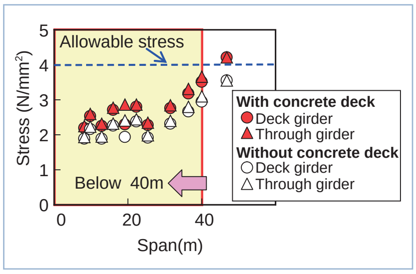

Fig. 2 Bearing stress at support concrete

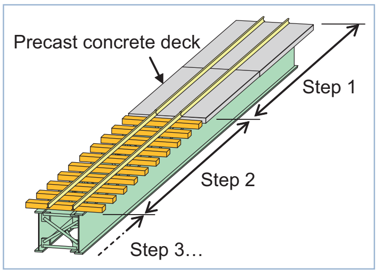

Fig. 3 Installation method with precast concrete decks

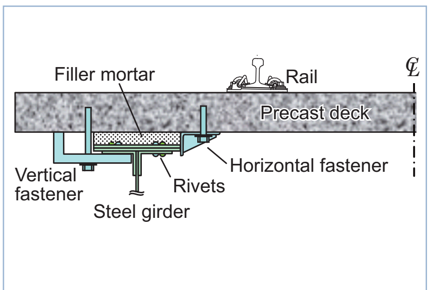

Fig. 4 Girder-deck connection

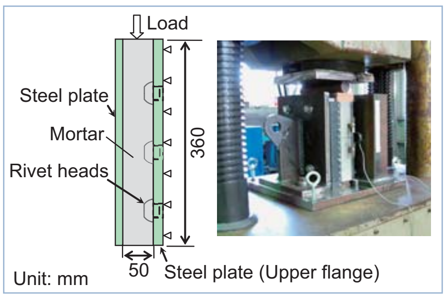

Fig. 5 Shear loading test

Table 1 Results of shear loading test

Type	Rivet heads	Treatment of upper flange	Strength (kN)	Strength per rivet head (kN)
A	6 heads	None	109.1	18.18
B	6 heads	Blasted	141.0	23.50
C	None	None	0.567	—

Development of a Contact-Loss Measuring System Using Ultraviolet Ray Detection

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Detection of contact-loss arcs is one of the most important methods of judging the current collection performance of the contact-wire/pantograph system, for which optical means are normally used. Until now, measuring contact loss characteristics used optical methods with detectors in the range of visible rays because of their simplicity and for various other reasons. These detectors, which intrinsically cannot be used in the daytime, often erroneously detect signal beams and lights other than contact-loss arcs, even during nighttime inspections. In other countries, however, detectors for wavelengths in the range of ultraviolet rays (contact-loss measuring systems using ultraviolet ray detection) have been developed, which are thought to be free from problems such as the inability to use them during the day and erroneous detection of miscellaneous lights at night. In the circumstances, therefore, there was an urgent need to develop a Japanese version of a contact-loss measuring system using ultraviolet ray detection.

The contact-loss measuring system using ultraviolet ray detection is fitted with a sensor to detect ultraviolet rays or a photoelectric cell near the pantograph. There are two methods to process the data obtained from the sensor. One is to transmit the data as electrical signals into the car. The other is to use quartz optical fibers for data transmission and convert the data into electrical signals in the car. The RTRI developed a version of the latter type, using low-priced plastic optical fibers in place of quartz optical fibers to limit the cost. The following description of the newly-developed system summaries the equipment, outlines its basic characteristics and gives the results of field running tests.

Figure 1 depicts the contact-loss measuring system that uses ultraviolet ray detection in the version with plastic optical fibers. As plastics absorb ultraviolet rays, the system has a unit at the light sensor to convert ultraviolet rays into visible rays. The conversion unit consists of an interference filter and a fluorescent glass plate. The unit extracts only ultraviolet rays from contact-loss arcs with the interference filter, converts them into visible rays with the fluorescent glass plate and transmits the resultant rays through the optical fibers.

Figure 2 illustrates the basic characteristics of the system. The interference filter in the conversion unit has a transmission range of 206 to 226 nm (see Fig. 2(a)). Figure 2(b) shows the voltage output characteristics of the system against the receiving contact-loss arc incident angle. When the arc incident angle is inclined by ±7° from the center, the output voltage decreases by 10% from that at the incident angle of 0°.

Figure 2(c) shows the characteristics of voltage output versus incident ray intensity. It reveals that there is virtually no reaction against the incident of direct sunshine.

Figure 3 compares the measurement results obtained by the conventional contact-loss measuring system using visible ray detection with those obtained by the new system, which were recorded in field running tests implemented on a narrow-gauge line at night. The two peaks at 0 to 10 sec indicate the occurrence of contact-loss, which were detected by both systems. The contact loss measuring system with visible ray detection recorded a waveform of a DC component superimposed with four pulses at 10 to 30 sec. The DC component is the pantograph monitoring light reflected on the tunnel wall, and the four pulses are the lights reflected on hinged cantilevers. In contrast, the contact-loss measuring system with ultraviolet ray detection presented satisfactory measurement results, without having such complicated peak-studded waveforms.

The RTRI expects that the contact-loss measuring system with ultraviolet ray detection described here will be fitted to inspection cars and test vehicles, so leading to stable transport and a reduction in the amount of maintenance work for railways.

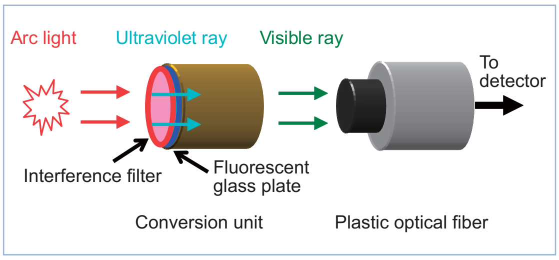


Fig. 1 An outline of the contact-loss measuring system with ultraviolet ray detection using plastic optical fibers

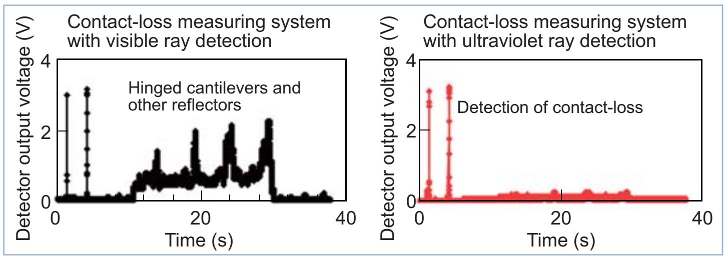
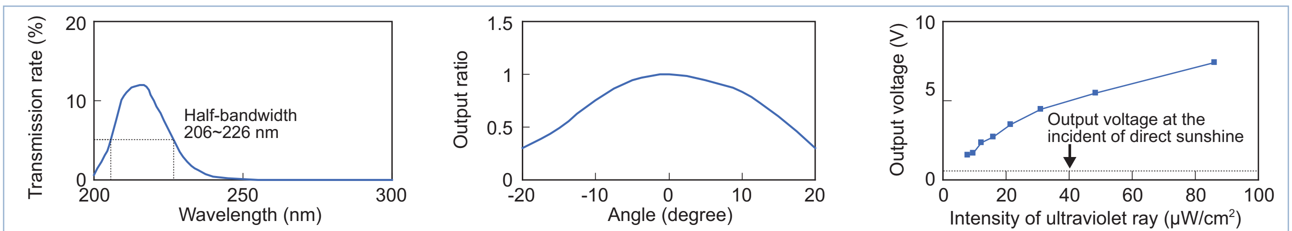


Fig. 3 Results of field running tests



(a) Transmission rate of interference filter

(b) Output voltage characteristics versus arc ray incident angle with the value at the incident angle of 0° taken as reference

(c) Output characteristics versus intensity of incident ultraviolet ray

Fig. 2 Basic characteristics of the contact-loss measuring system with ultraviolet ray detection

A Method of Managing Wheel Loads and Lateral Forces Using Axle-Box Acceleration

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Railway tracks in Japan are maintained to standards that meet or improve on the criteria determined by track inspection cars for safe operations of train. This assumes that the wheel loads and lateral forces exerted on the rails do not exceed the specified safety limits. In practice, however, this assumption cannot be taken for granted because of short wavelength track irregularities that cannot be measured by track inspection cars. The excessive wheel loads or lateral forces are thought to lead to a rapid increase in track irregularities or a swift deterioration in track materials. It is important, therefore, to correctly assess the wheel loads and lateral forces that are actually generated by rail vehicles in service.

To estimate the wheel loads and lateral forces caused by short wavelength track irregularities, the Railway Technical Research Institute (RTRI) is now promoting researches on the application of axle-box acceleration. The axle-box acceleration is the vibration acceleration measured at the axle-box supporting the axle. It is known that the axle-box acceleration in the vertical direction correlates closely with the wheel load and that in the lateral direction it correlates with the lateral force. See Fig. 1.

The RTRI carried out frequency analysis of vertical/lateral axle-box accelerations and discussed a technique to estimate wheel loads/lateral forces from axle-box accelerations by applying the frequency response method to the frequency bands where the accelerations correlate closely with the wheel load/lateral force. The frequency response method involves performing inverse Fourier transformation on the frequency response functions of input/output waveforms and applying the result to the input waveform as a finite impulse response (FIR) filter to obtain the estimated output waveform.

Track irregularities also cause comparatively long wavelength variations in the wheel load and lateral force. Therefore, a technique has been developed to estimate wheel loads and lateral forces by applying the frequency response method to these long wavelength variations. In this study, the RTRI used both track irregularities and axle-box accelerations to estimate the variations in the wheel load and lateral force. See Fig. 2.

To obtain the waveforms of wheel loads and lateral forces by this method, the RTRI took the following three steps: (1) estimation of wheel loads having wavelengths of 6 m or more from cross-level irregularities and lateral forces having the same wavelengths from alignment irregularities, (2) estimation of wheel loads and lateral forces with a wavelength less than 6 m from axle-box accelerations and (3) superimposition of the results of (1) and (2) for each quantity. Figure 3 shows an example of the lateral force estimated from axle-box lateral acceleration. It proves that the occurrence of large lateral forces at 25 m-spaced rail joints can be estimated with great precision.

To control large wheel loads and lateral forces, it is necessary to eliminate short wavelength track irregularities. For this purpose, the RTRI intends to use track irregularities measured by the asymmetry chord offset method that enables assessment of track irregularities of shorter wavelengths than those obtained by the 10 m-chord offset method. Figure 4 shows a control flow chart for wheel loads and lateral forces using both axle-box accelerations and track irregularities obtained by the asymmetry chord offset method. According to this flow chart, the first step is to apply the above estimation technique to determine the locations where large wheel loads and lateral forces are anticipated to occur. Then, the next step is to carry out maintenance at the locations where wheel loads and lateral forces are anticipated to exceed the reference value by using the short chord offset obtained from the asymmetry offset chord track irregularities. This is because, as the wheel loads and lateral forces caused by short wavelength track irregularities largely depend on the train running speed, the most efficient way of remedying the problem is to give priority to elimination of short wavelength track irregularities at those locations where large wheel loads and lateral forces occur.

It is expected that the technique of using axle-box accelerations can also be applied for various other track management purposes apart from those introduced above for controlling wheel loads and lateral forces. The RTRI will promote research on this topic from different viewpoints in the future as well.

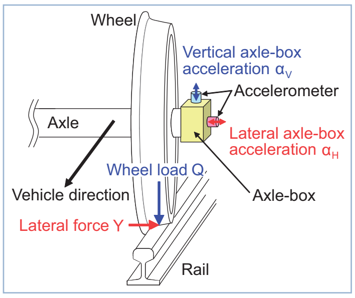

Fig. 1 Axle-box acceleration versus wheel load and lateral force

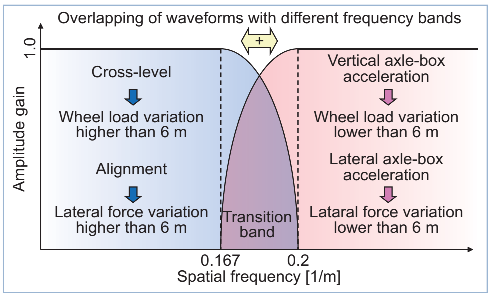

Fig. 2 A technique to estimate wheel load and lateral force

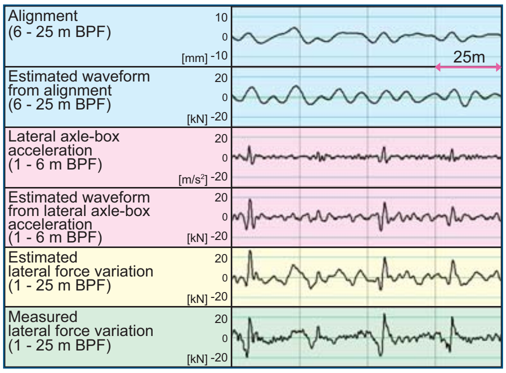

Fig. 3 An example of lateral force estimated from lateral axle-box acceleration

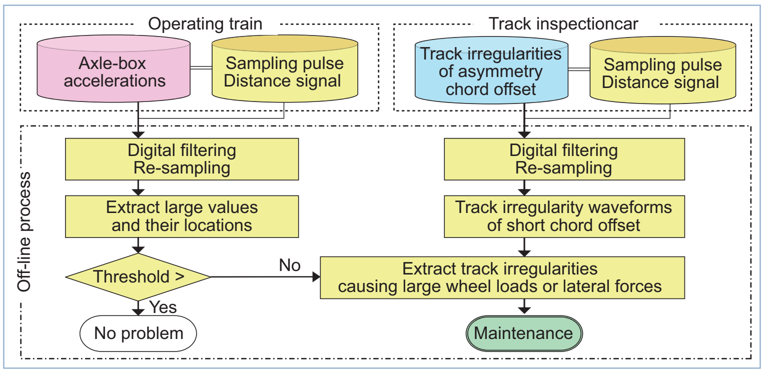

Fig. 4 A control chart for excessive wheel loads and lateral forces