Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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GENERAL INFORMATION

ARTICLES

FOREWORD

Masao UCHIDA
Executive Director

The Mid Niigata Prefecture earthquakes of October 2004 struck from directly under the region with a maximum magnitude of 6.8 and caused numerous casualties, destroyed many houses and disrupted traffic and utility networks. The seismic activity also derailed a Shinkansen train — this was the first time, since the Tokaido Shinkansen began commercial operations in 1964, that a Shinkansen train had ever derailed.

The cars that derailed continued moving a certain distance with parts of their undercarriage appearing to hug the rails. Luckily, the train stopped without leaving the track dangerously or overturning, and there were no casualties among the hundreds of passengers. But the derailment was a wakeup call to the operators of the Shinkansen system and the country as a whole. It also imposed two vital tasks on those of us engaged in rail research and development.

One of those tasks is to identify the mechanisms involved in an earthquake-induced derailment. This involves a number of steps. First, the seismic waveforms at the ground surface near the derailment are hypothesized from the waveforms recorded at the station that monitors seismic activity. Next, track surface vibrations are hypothesized from the nature of elevated bridge vibrations. Then, the vehicle dynamic behavior in response to significant track displacements during an earthquake is analyzed to determine the probability and nature of a derailment.

The other task is to take all possible measures to avoid derailment. These measures include:

- safeguarding the tracks and other infrastructure from destruction or damage;
- developing more sophisticated systems for early earthquake detection;
- installing rail guards to prevent a future derailment.

However, if the quake is extremely severe, it may not always be possible to completely avoid a derailment even where the railway infrastructure is sound. It is therefore necessary to implement extra measures so that even if a train derails it will not fall off the track bed, overturn, or collide with an oncoming train.

Japan is an earthquake-prone country, and it is fully recognized that rail infrastructure must be sufficiently strong to withstand seismic activity. Although ensuring the running safety of trains during and after an earthquake is a technical problem that must obviously be fully addressed, it is no easy task in view of the difficulty of identifying all relevant dynamics, and the huge cost of implementing effective safety measures. Railway Technical Research Institute considers rail transport safety to be its most vital research and development aim, and will continue tackling rail safety issues in order to develop effective, practical solutions.

内田雅夫

Promoting the International Standardization Activities of Railway Technology

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The International Standards Center of the Railway Technical Research Institute (RTRI) serves as the secretariat in Japan for the development of international electric and electronic standards for railway technology. International standards in this field are prepared by TC9 (Electrical Equipment and Systems for Railways), one of the Technical Committees (TCs) established under the International Electrotechnical Commission (IEC).

International railway standards used to be applied mainly for equipment specifications and test methods, but over the last few years standards encompassing an entire railway system are becoming more prevalent. These standards include the IEC62236 Series (Railway Applications – Electromagnetic Compatibility) and IEC62278 (Railway Applications – Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)). Because this trend toward standardization of an entire rail system is expected to intensify in the future, we believe that our systematic promotion of international standardization will become even more significant.

Entities involved in IEC/TC9 activities in Japan are shown in Fig. 1. The Japanese Industrial Standards Committee (JISC), an entity functioning within the Ministry of Economy, Trade and Industry, maintains direct contact with the IEC, and conducts various activities for the International Organization for Standardization (ISO) while promoting standardization in Japan. The Japanese National Committee for IEC/TC9 examines IEC/TC9 issues in Japan. As the secretariat for this committee, RTRI serves as the liaison office for JISC. The committee consists of about 30 members representing railway operators, rail-related industries, academic societies, governments and other entities. Japanese proposals concerning specific draft standard advanced by the IEC are prepared by working groups established under the committee. Each working group consists of experts in their chosen field.

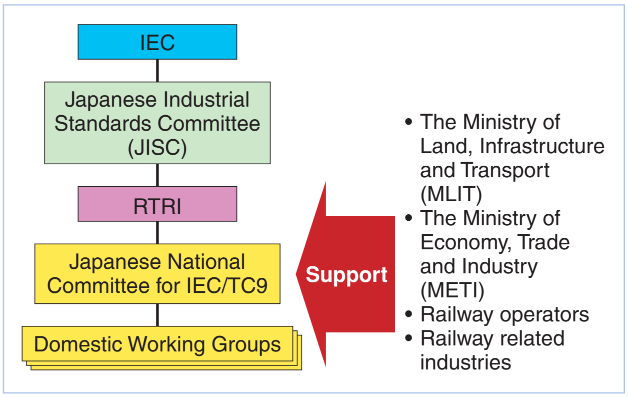

Figure 1. Japanese entities promoting rail system standardization

At the IEC, standards are developed by working groups composed of experts from various countries, including Japan. Japan never fails to send a delegation to IEC/TC9 annual plenary meetings. In 2002 and 2003, working groups participated in meetings in Tokyo, and these meetings were organized by Japanese staff. In addition, an IEC/TC9 plenary meeting was successfully held in Tokyo from November 14 to 17, 2005.

RTRI's International Standards Center performs the secretarial operations for all those activities.

Only a few years have passed since Japan began participating actively and systematically in the international railway standardization process, and we intend to promote these activities even more in the future. We hope that through participation in the activities mentioned above, we will be able to contribute to the expansion of the transport modal share of railways, and to the global advance of railway technology.

Figure 2. IEC/TC9 Plenary meeting in Tokyo

Figure 3. Welcome party held prior to the plenary meeting

Verification of Regenerating and Absorbing Functions for a Ground-based Electrical Power Storage System

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Recent remarkable advances in power storage media have led to the development of new power supply systems for electric motor vehicles and for power supply backups. The electric double layer capacitor (EDLC) is an especially promising power storage medium. Its strong points include rapid charging and discharging capacity, long life, easy maintenance, low pollution and high efficiency. Ongoing developments are rapidly making it possible to increase EDLC capacity.

We have developed a ground-based power storage system that utilizes an EDLC as the storage medium. The system uses a step-up/step-down chopper unit to control the electrical charging and discharging. System configuration is shown in Fig. 1.

We installed the system at the end of a feeding circuit, as shown in Fig. 2, then carried out verification tests to ascertain how effectively the regenerated power was utilized. The tests involved charging electricity to the power storage during regenerative operation of the train, and discharging electricity from the power storage during powering of the train. The test was carried out on a 15.5 km double-track section. On this section, each trainset consists of six cars, all capable of regenerative operation. Headway is about 4 minutes during rush hour and about 7 to 10 minutes at other times. The feeding voltage is 750 V DC, and DC substations have been installed at intervals of every one or two railway stations.

Fig. 3 shows various charging characteristics (measured over a period of 2 minutes) when the power storage unit was being charged with the maximum electric current. In the third and fourth graphs, the positive currents represent charging, while the negative currents represent discharging. The following facts can be ascertained from Fig. 3:

(1) The maximum current charged to the power storage unit was 866 A.
(2) The feeding voltage at Osakako Station, while the power storage was being charged, was never higher than 860 V, suggesting that excessive voltage rises were restrained.
(3) The EDLC voltage rose from 317 V to a maximum of 430 V while the power storage was being charged. However, that maximum voltage was still lower than the rated maximum voltage (500 V), and no problems with the charging energy capacity of the power storage unit were seen.
(4) The maximum charging power of the EDLC was 637 kW and the charging energy was 4,735 kJ, both close to the maximum rated values.

The verification tests confirmed that our power storage system can greatly improve energy recovery rates. (Without the power storage system, only a fraction of the energy regenerated by the train while braking just before stopping at station can be supplied to a remote load.) The tests also confirmed that charging of the power storage system with regenerated power restrained the rise in feeding voltage at station by tens of volts, on average.

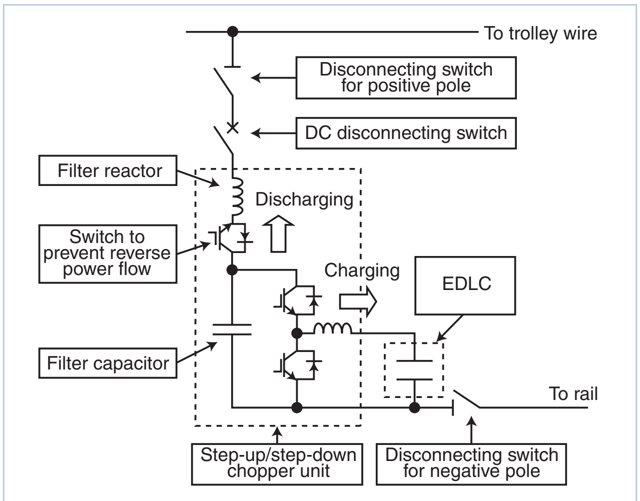

Figure 1. Power storage system configuration

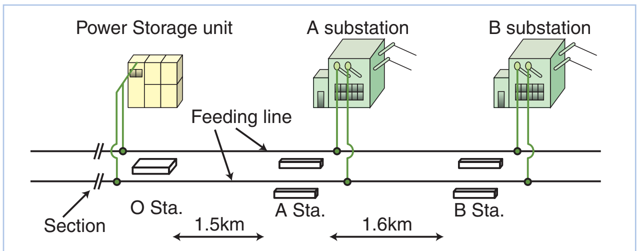

Figure 2. Test section

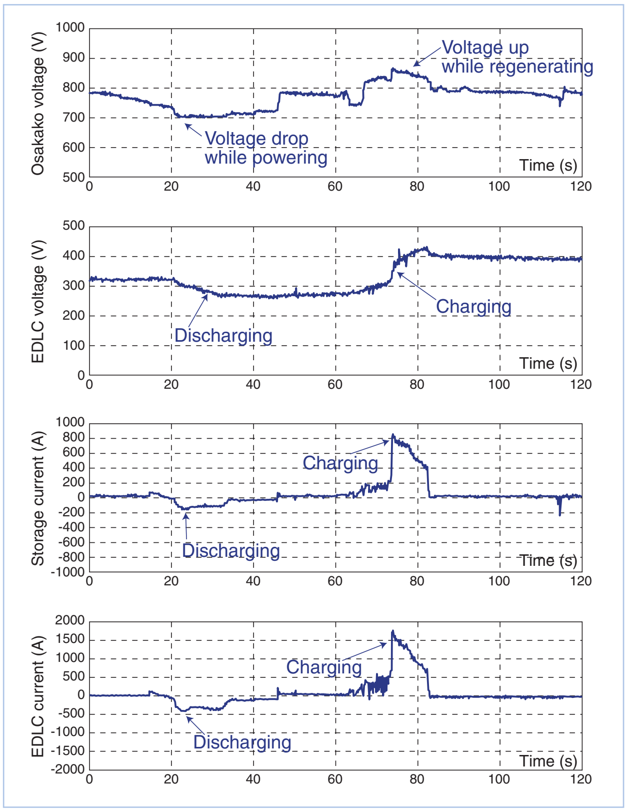

Figure 3. Charging characteristics of regenerated power

Real-Time Processing of Pantograph Contact Force Algorithm

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Shunichi KUSUMI Senior Researcher, Laboratory Head, Contact Line Structure, Power Supply Technology Division

1. Introduction

The contact force between a pantograph and the contact wire largely represents the pantograph's dynamic behavior, including loss of contact. Therefore, contact force can be used to quantitatively understand the contact performance of a pantograph. And, since the contact force varies according to the installed condition of catenaries, one can assume that contact force can be used in the assessment of the installed condition of catenaries as well. We therefore built a test system capable of real-time processing (output) of contact forces that could formerly be processed only on an off-line basis, and confirmed the system performance in running tests.

2. Measuring contact force with a pantograph

The pantograph is modeled as shown in Fig. 1. Assuming the inertial force acting upon system 1 as Fi, the aerodynamic force acting upon system 1 as Fa, and the sectional force acting upon the interface between system 1 and system 2 as Fd, contact force F can be expressed as follows.

$$F = Fa + Fi + Fd \text{ .... (1)}$$

Thus, contact force F can be calculated as the sum of Fi, Fd and Fa. Ordinarily, however, aerodynamic force Fa can hardly be measured. Therefore, the sum of Fi and Fd is first determined during train operation, and then the force equivalent to Fa is added to that sum to obtain the contact force.

Using a Shinkansen train pantograph as a model, we studied an algorithm for real-time output of the contact force and built a prototype data-processing system installed in a laptop computer. To correct the aerodynamic force, a table of relevant data for different train speeds in open and tunnel sections was prepared so as to permit calculating the aerodynamic force under specific conditions (train speed, etc.). Fig. 2 shows the appearance of the prototype system. This system was employed in running tests using a Shinkansen train. In the tests that lasted many hours, the system was capable of correctly outputting contact force data on a real-time basis.

3. Characteristics of contact force waveforms

Takahiro FUKUTANII Shunichi KUSUMI

Fig. 3 shows the contact force waveform measured in a heavy compound catenary section of the Shinkansen, and Fig. 4 shows the results of a spatial frequency analysis of the contact force. From Fig. 4, it can be seen that the contact force contains three variable components ascribable to the contact wire structure—about 0.02 (l/m) support spacing cycle, about 0.08 (l/m) dropper spacing cycle, and about 0.16 (l/m) hanger spacing cycle.

Fig. 3 indicates that a slightly higher contact force—about 270N—occurred at the overlap section of contact wires. It is known that if the vertical configuration of catenaries at the overlap section is improper, the contact force increases and local wear of the contact wire tends to occur easily. The overlap section at which the higher contact force occurred was still free of local wear because the contact wire had recently been relined. However, it is considered likely that local wear due to the slightly higher contact force will occur at that point sooner or later.

Furthermore, from contact force it is also possible to predict the occurrence of a marked strain in the contact wire and a loss of contact. Thus, measuring the contact force is useful not only in understanding current-collecting performance but also in assessing the installed condition of catenaries. We are therefore now studying assessment techniques based on contact force.

4. Conclusion

By developing and testing a prototype data processing system, we confirmed that real-time processing of our contact force algorithm is possible even with a laptop computer. In the future, we intend to upgrade the method for assessing catenary conditions using contact force waveforms.

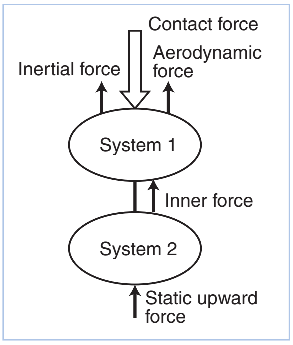

Figure 1. Forces acting on a pantograph

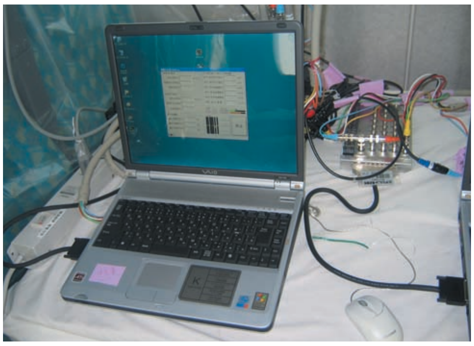

Figure 2. Contact force real time processing system

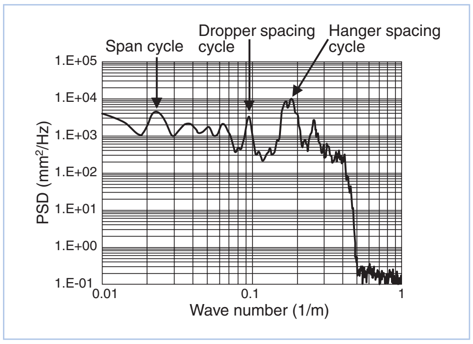

Figure 4. Frequency analysis of contact force

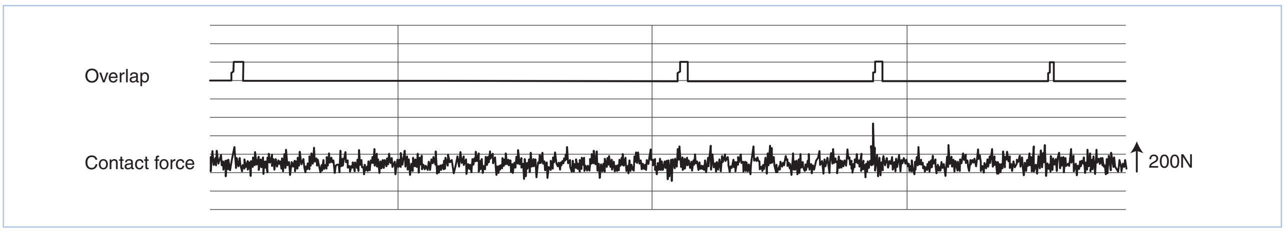

Figure 3. Contact force waveform

Use of Continuous Welded Rail (CWR) Track with Turnouts

Hideaki YANAGAWA
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CWR tracks are effective in reducing noise, vibrations and related problems. They also reduce the amount of track maintenance and greatly improve ride quality. To promote their more widespread use, technical advances are needed to permit the installation of CWR track even in bridges, turnouts, and other infrastructure where CWR track cannot generally be laid yet.

Research has clearly identified conditions for laying CWR track for a single turnout on ballasted track. The JR group and other railway companies already have many experiences in laying CWR track for turnouts on ballasted track, however only for the case where one turnout exists in the track section. On ballasted track sections with two or more successive turnouts, CWR tracks have been very seldom to be laid for the turnouts, because no reliable analytical method has been established yet.

We therefore have established a finite element model for evaluating the CWR force at track sections with successive turnouts, and proposed a new method of analysis based on the model. This method can calculate the temperature-dependent axial force and the amount of expansion and contraction of each CWR, corresponding to turnout type, turnout location, and track conditions, including rail type and ballast resistance. The method can be also applied to even the case of multiple turnouts laid in a large yard or depot. From the estimated results of CWR force, it is possible to calculate the required lateral resistance of ballast, and to examine other requirements for laying CWR track on the sections with successive turnouts. We confirmed the validity of our analysis method by carrying out field measurement tests at CWR on ballasted track with two successive turnouts (see Figs. 1 and 2).

Fig. 3 shows a turnout whose sleepers are fixed directly to the roadbed concrete. The sleepers are bolted to the roadbed concrete, and the rails are rigidly fixed to the sleepers using washers. Since the rail creepage resistance at a rail fastening is larger than that on a slab track, longitudinal resistance characteristics in the turnout section must be examined if CWR track are to be laid for turnouts fixed directly to the roadbed concrete on a viaduct. In order to identify the CWR force characteristics at turnouts on direct fixation track laid on a viaduct, we developed a program to analyze the CWR force in relation to the expansion and contraction of viaduct girders due to temperature changes. An analysis made with this program showed that when a turnout was laid near the girder end, the maximum CWR force often exceeded the critical value (980kN) for the longitudinal load on the CWR specified in the design standards for the railway structures (see Fig. 4). Further analyses clarified the relationship between girder length, bearing layout and CWR force, making it possible to identify the conditions for installing turnouts on direct fixation CWR track sections.

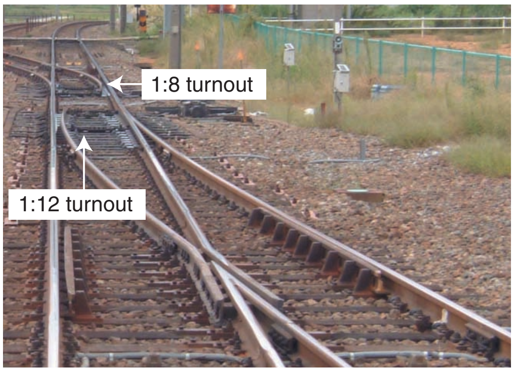

Figure 1. CWR laid with two turnouts in succession

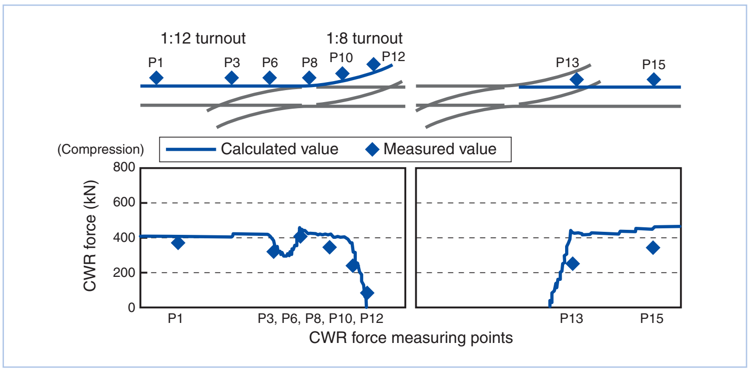

Figure 2. CWR force distribution

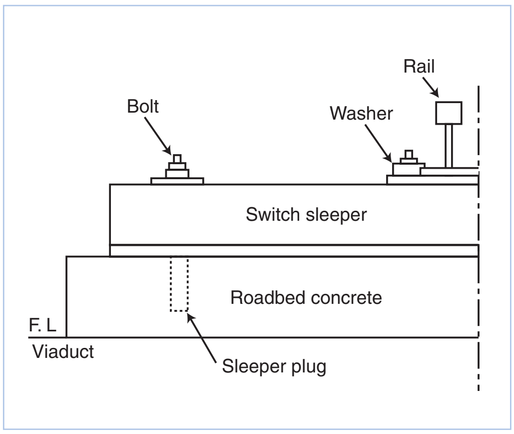

Figure 3. Direct fixation structure of turnouts

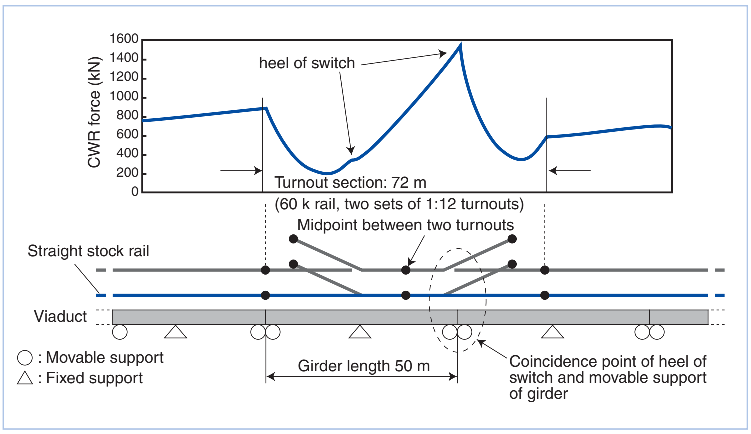

Figure 4. Sample analysis of CWR forces in CWR track with successive turnouts on viaduct

Evaluating Track Geometry Using a Train Vertical Motion Prediction Model

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Track conditions are normally evaluated using the amplitudes of track geometry waveforms. However, an evaluation of track conditions using vehicle dynamic response on the track better suits the purpose of track maintenance, which is to ensure good riding comfort and high running safety. The author has therefore developed a method for accurately predicting vehicle dynamic response, with a comparatively light load on the computer.

To predict the dynamic response of a complicated vibration system such as rolling stock, either of two methods is commonly used. In one method, the response is directly obtained by solving kinematic equations. In the other, measured input and output values are transformed into a frequency band by Fourier transformation to obtain a frequency response function. However, these methods have certain drawbacks - for example, they require a huge amount of calculation work, or involve calculation errors that are not insignificant. It may be said, therefore, that they are unsuitable for practical use in track maintenance.

The author's adopted method involves applying to railways a technique called system identification. In this method, the vehicle transfer function is directly identified on the space axis (or time axis) from measured track geometry and time-serial data for vehicle response, and a digital filter equivalent to the identified function is used to predict vehicle response. This method requires less computer capacity, and offers greater prediction accuracy.

As a case in point, since track maintenance units in the JR Group already have a database system for track maintenance and management that uses digital signal processing technology, Group members can easily introduce the new prediction method that employs a digital filter.

Since the method can easily be expanded into a multi-input model, it also permits predicting even vehicle responses such as horizontal vibration and wheel load that are influenced by various track geometry parameters.

Examples of predicted and measured vertical acceleration waveforms are shown in Fig. 1. They represent the predicted vertical motion of a Shinkansen car. The predictions only require obtaining the sum of the results of polynomials of degree 50 or so, hence the calculation time is extremely short. Even with such a short calculation time, the predicted waveforms agree well with the measured waveforms, as shown in Fig. 1.

The author has developed a technique to apply this method to predict wheel load, as well as to predict horizontal vibration and lateral forces while the train is passing through a curved section. To permit application of the method to track sections where train speed is variable, and to vehicle models whose measurement data is unavailable, the author is presently studying a vehicle response prediction technique that combines time-serial simulations with this method.

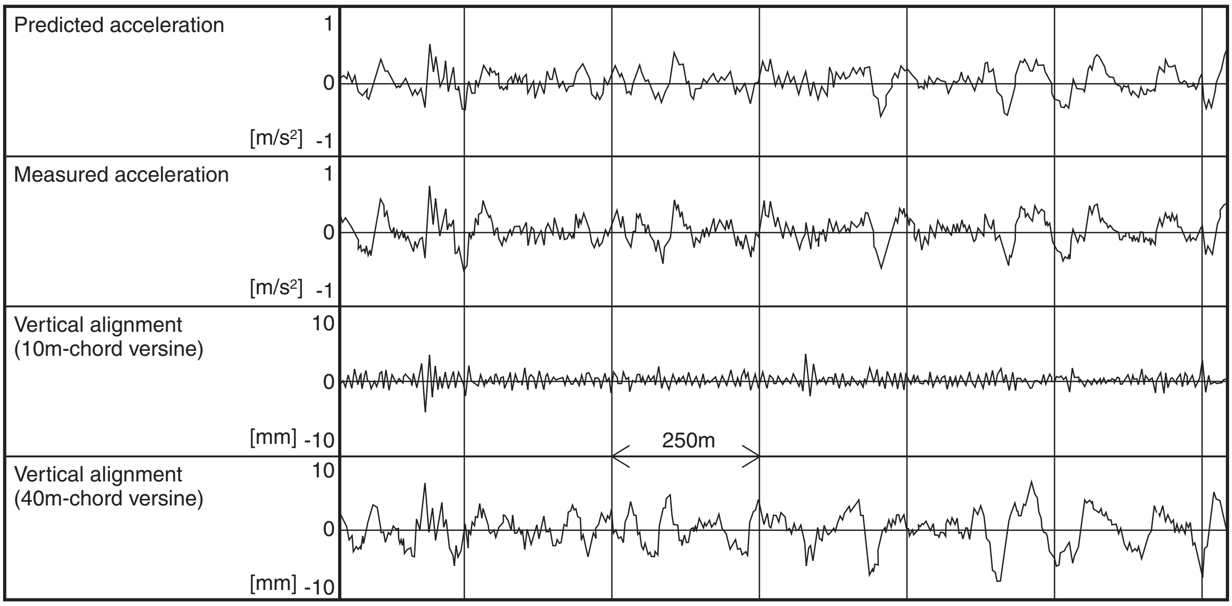

Figure 1. Predicted and measured vertical acceleration waveforms (Frequency band=0.01~0.16 [1/m])