

# Introduction of Evaluation Testing Technology and Friction Modifier

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## Abstract

*Nippon Steel Railway Technology Co., Ltd. conducts evaluation tests of products manufactured at the Kansai Works of Nippon Steel Corporation, as well as friction modifiers to reduce wear of wheels and rails for railroad companies. This paper introduces these technologies.*

## 1. Introduction

As global environmental problems mount, expectations are also growing for railroads as a highly energy-efficient means of transportation. To date, many technology developments have been conducted to ensure the safety and convenience of railroad transportation. Japanese railroads, including their subsequent maintenance and management, are highly touted both at home and abroad.

On the other hand, due to the declining birthrate and aging population, as well as changes in the working environment, it is becoming increasingly difficult to maintain and manage railroad facilities using current methods.

Nippon Steel Railway Technology Co., Ltd. (NSRT) conducts performance evaluation tests that play a part in the technology development and quality assurance of wheelsets and bogies manufactured by Nippon Steel Corporation. Utilizing our technology, we have expanded our business of evaluation tests and other services for railroads within the premises of Nippon Steel's steelworks and for railroad operators. In addition, we have contributed to stable railroad transportation by providing friction modifiers that suppress the wear of wheels and rails and reduce the noise generated when trains pass through curved sections.

In these situations, NSRT is expanding its solutions business by utilizing not only evaluation testing but also rapidly advancing IT technology. In this report, we introduce the technologies that NSRT is deploying and their prospects.

## 2. Measurement and Evaluation Technologies for Railroad Operators

### 2.1 Measurement of wheel load, lateral force, and other quantities

#### 2.1.1 Measurement of wheel load and lateral force

The running safety of railroad vehicles is evaluated based on the

wheel load  $P$  and lateral force  $Q$  acting between the wheels and rails, as shown in **Fig. 1**, and on the derailment coefficient, which is the  $Q/P$  ratio. When evaluating their wheel load  $P$  and lateral force  $Q$ , the vehicles are equipped with special wheelsets known as PQ wheelsets, as shown in **Fig. 2**. Their data are recorded with measuring devices, and special analysis tools are used to check their safety over the entire route.

In these cases, on-board measurement helps to evaluate the performance of the vehicles in all running sections, but this performance evaluation is limited to specific wheelsets or bogies where measurement sensors such as PQ wheelsets are installed. On the other hand, on-ground measurement is limited to evaluation only at the measurement points but can evaluate the performance of all

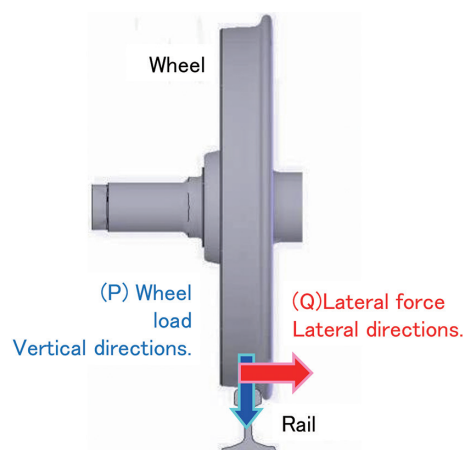


Fig. 1 Contact force between wheel and rail

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passing vehicles.<sup>1)</sup>

In addition, the development process of wheelsets and bogies for railroad vehicles and the results of various studies and investigations have revealed that the wheel load P and lateral force Q acting between the wheels and the rails change from moment to moment. For example, when the on-board measurement of the wheel load and lateral force (hereafter abbreviated as on-board PQ measurement) is performed by running the same vehicle over a specific section multiple times, the results may differ over multiple runs. When the on-ground wheel load and lateral force measurement (hereafter abbreviated as on-ground PQ measurement) is conducted at specific locations, the results may differ depending on the time zone and the vehicle type.

NSRT can perform measurement and evaluation using these two methods. NSRT makes effective evaluations by taking advantage of the characteristics of the respective methods and using them appropriately according to their purpose.

Recently, the effectiveness of on-ground measurement has increased for the purpose of not one-time measurement and evaluation but constant monitoring, such as checking changes in vehicle performance over time, vehicle behavior, and lubrication conditions from the ground.

In addition to measuring the wheel load and lateral force, we also evaluate the performance of vehicles using a wide range of measurement methods, such as measuring the stress of various bogie components such as bogie frames and axles, measuring the temperature of brake disks and pads, and measuring noise in the railroad vehicles and at the railroad waysides.

**2.1.2 On-board measurement of wheel load and lateral force and overview of PQ wheelsets**

Nippon Steel measures the PQ on-board to check the performance of newly developed wheelsets and bogies for railroad vehicles in the development stages and before the delivery of the wheelsets and bogies to railroad operators.<sup>2)</sup> In addition, the PQ wheelsets used in this measurement have strain gauges precisely attached to specially processed wheels, as shown in Fig. 3, making it possible to measure the wheel load P and lateral force Q acting on the wheels.

NSRT has been in charge of on-board PQ measurement and PQ wheelset manufacture for Nippon Steel for many years. NSRT is one of the few companies in Japan that can do these tasks.

**2.1.3 On-ground measurement of wheel load and lateral force**

As shown in Fig. 4, on-ground PQ measurement involves measuring the wheel load P and lateral force Q acting on the rails from the shear strain generated in strain gauges attached to the sides and bottom of the rails.

Based on the results of on-board PQ measurement, the usefulness of on-ground PQ measurement has increased to compensate for its disadvantages. The strength of NSRT is that it can measure and evaluate the PQ both on board and ground.

**2.2 Deployment of measurement and evaluation technologies to continuous monitoring devices**

One of the measures to ensure the running safety of railroad vehicles is the management of wheel load balance. When a train runs on a curve with the left and right wheel loads unbalanced in the

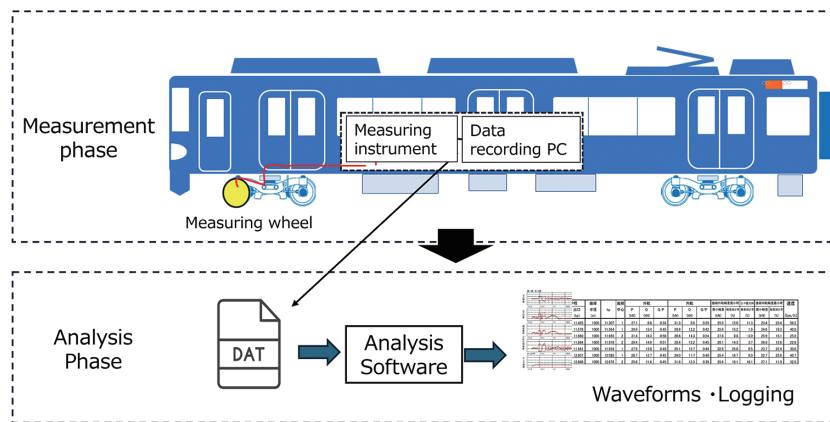


Fig. 2 Onboard measurement of wheel/rail contact force

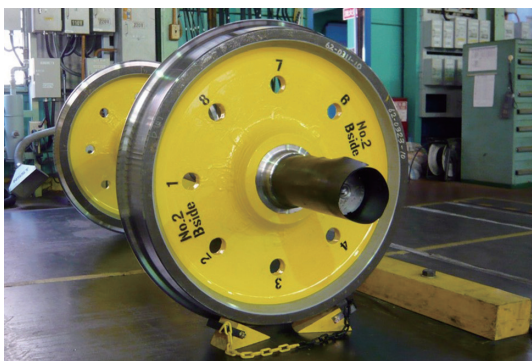


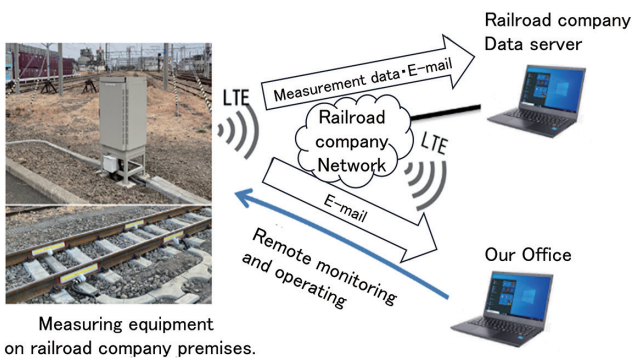
Fig. 3 Wheel set for contact force between wheel and rail measurement



Fig. 4 Rail for contact force between wheel and rail measurement



Fig. 5 Sensor for wheel load measuring device



Measuring equipment on railroad company premises.

Fig. 6 Wheel load measuring device with internet connection

same wheelset, the risk of derailment may increase. This condition has been one of the causes of past derailment accidents. Since such derailment accidents, railroad operators have performed the adjustment and control of wheelsets during periodic inspection according to a ministerial ordinance issued by the Ministry of Land, Infrastructure, Transport and Tourism<sup>3,4)</sup> and have introduced devices for measuring the wheel load. In addition, similar management is performed on individual freight cars. When the freight cars are loaded unbalanced, the wheel load balance may be lost. This situation also makes it necessary to measure the wheel load of loaded freight cars.

To meet these requirements, NSRT supplies wheel load measurement devices combined with IT technology on the basis of on-ground wheel load measurement and evaluation technology shown in Fig. 5.

The measurement results of wheel load measuring devices equipped with communication functions and installed at the strategic points of each railroad operator, as shown in Fig. 6, are sent to the in-house server of the railroad operator. When a wheel load anomaly is detected, an alert is sent to the server before the next train leaves its depot onto its commercial line. Also, the operating status of the wheel load measuring devices can be checked from the NSRT office, enabling rapid response in the event of a device anomaly.

The development and deployment of devices combining measurement and evaluation technologies with IT technology enable us to meet the demand for continuous monitoring for the purpose of maintaining and managing railroad vehicles and related equipment.

### 2.3 Deployment of measurement technology combined with videos

Measurement technology has made great advances not only in hardware, such as sensors but also in software, which is IT technology.



Fig. 7 Examples of measurements using video

For example, it is now easy to perform the synchronized measurement of analog sensor signals with global positioning system (GPS) information and videos, which were previously difficult to combine in the past. Until now, the behavior of measurement objects has been inferred and evaluated from sensors' measurements. As shown in Fig. 7, it has now become easier to grasp the actual behavior and location of the objects from visual video information and real-time position information.

These technologies are already spearheaded in the automobile sector. By incorporating them and improving measurement and evaluation technologies, it is possible to deploy them for the above-mentioned continuous monitoring.

### 2.4 Application of measurement and evaluation technology to railroads within steelworks

Each steelworks of Nippon Steel has its own internal railroads for transporting materials, products, etc. The configurations of vehicles, tracks, rails, etc., of these internal railroads are not significantly different from those of general railroad operators such as JR companies. NSRT can thus deploy its measurement and evaluation technologies to such railroads.

One example is the implementation of on-ground PQ measurement to investigate the conditions of vehicles on such internal railroads. The results of these investigations are used to determine whether or not vehicles can be used and whether or not the vehicles require maintenance. This condition monitoring serves the same purpose as the wheel load measuring devices mentioned above and contributes to the stable operation of railroads within steelworks.

Also, the weight of the cargo transported by internal railroads is heavy. While the wheel load of railroad operators' vehicles is a maximum of about 80 kN, the wheel load of vehicles in the internal railroads of the steelworks can exceed 150 kN. This condition places large loads on the vehicles, tracks, and rails. Constant monitoring is considered useful for checking for the occurrence of anomalies, etc.

## 3. Technology for Adjusting Friction between Wheels and Rails

### 3.1 Lubrication between wheels and rails

As mentioned above, the running safety of railroad vehicles is evaluated in terms of the wheel load  $P$  and lateral force  $Q$  that act between the wheel and rail, as well as the derailment coefficient, which is the  $Q/P$  ratio. Consequently, measures such as optimizing the wheel shape and adding steering mechanisms to bogies have been taken to reduce the lateral force produced when running on curves.

Lubricating the wheels and rails helps to reduce the lateral force produced and, at the same time, to suppress the wear of the rails and

wheels in curved sections and the generation of high-frequency noise. This is because the frictional force developed at the contact surfaces between the rolling wheels and the rails is reduced by the lubrication.

However, conventional lubrication that mainly relies on oil application has the drawback of causing wheels to slip or skid as the coefficient of friction declines significantly. Care must be taken when applying lubrication.

**3.2 Friction modifiers**

Friction modifiers are available as lubricants to take the place of oil and grease conventionally used for lubrication between the wheels and rails. As an L.B. Foster agent, NSRT sells friction modifiers and their applicators to domestic businesses.

Friction modifiers come in two types: solid products molded from resins and water-based liquid products, depending on the application method. Friction modifiers can be used to maintain the coefficient of friction between steel components at a nearly ideal level of about 0.3. They provide a lubricating effect without drastically lowering the coefficient of friction like oil does. The effects of friction modifiers are described below.

**3.3 Effects of friction modifiers**

**3.3.1 Reduction of rail wear**

One example of rail wear is corrugation. Corrugation often occurs on the top surface of the inner rail in a curve and causes vibration and noise when a vehicle runs a curve. It is believed to be mainly caused by the high frictional force generated between the wheel and the rail. As shown in Fig. 8, a wheel sensor detects the passage of a vehicle, and top wiping bars attached to the rails discharge the friction modifier. The wheels tread the friction modifier and spread it wide over the curved rails to improve the lubrication condition and reduce the occurrence of corrugation.

The number of passing wheels and the friction modifier discharge time can be set with a controller in the main unit. Optimal friction modifier application conditions can be provided for specific installation locations.

Figure 9 shows the change in the occurrence of corrugation over time in curved sections of a railroad operator. The application of the friction modifier is shown to prevent the spread of corrugation. If the corrugation grows, the affected rails are ground or replaced with a dedicated maintenance vehicle, but rail grinding and replacement

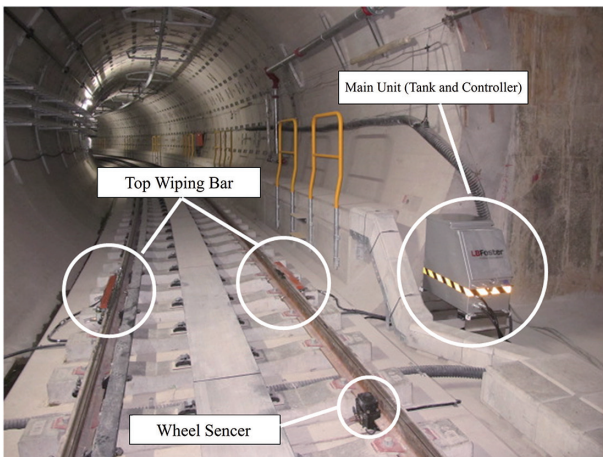


Fig. 8 Application equipment of friction modifier

are very costly. Application of the friction modifier may decrease the occurrence of corrugation and reduce the cost and labor of rail maintenance and management.

**3.3.2 Reduction of noise**

There was a case where the application of a friction modifier improved the lubrication condition at a railroad location with a noise of more than 90 dB and helped to reduce the noise at the railroad location to a maximum of about 80 dB, as shown in Fig. 10. In addition, Friction modifiers are also effective against brake squeal, which is a type of high-frequency noise, and help to improve the environment along the railroad lines, as shown in Fig. 11.

**3.4 Reduction of wheel and rail wear**

Oil and grease are commonly used to prevent the wear of wheel

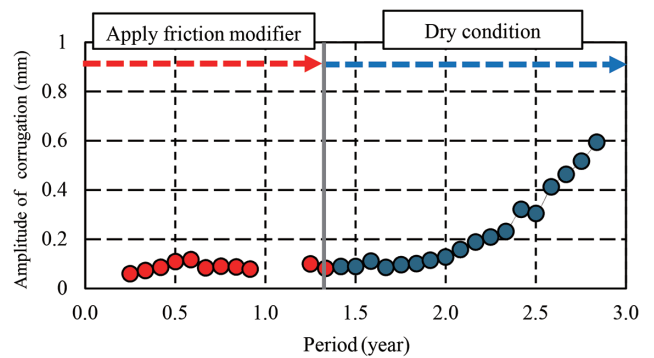


Fig. 9 Effect of friction modifiers on rail corrugation

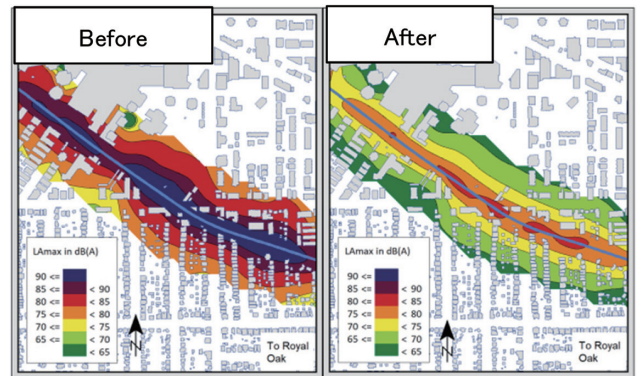


Fig. 10 Reduction of roadside noise by friction modifiers

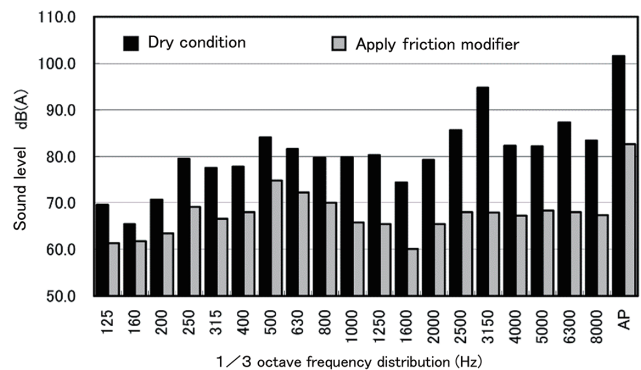


Fig. 11 Noise reduction effect by friction modifiers

flanges. On the other hand, the use of oil as a friction modifier is restricted for overseas railroads in relation to environmental regulations in Europe. As a substitute for oil, solid lubricant LCF (Low Coefficient of Friction) is widely used. NSRT also handles LCF and supplies it to domestic railroad operators for use as a friction modifier to reduce flange wear. It is also used on the railroads of some of the domestic steelworks.

Flange wear is likely to occur on subways with many sharp curves and freight railroads carrying heavy loads. On such subways and freight railroads, the lateral force (Q) that causes wheel flange wear and rail side wear, as shown in Figs. 12 and 13 tends to be large. As the lateral force thins and uprights the wheel flange, the flange may break, and vehicle derailment may occur under certain conditions. It is thus important to maintain the wheel shape. LCF is made of a resin-based material containing molybdenum disulfide and is directly pressed against the wheel tread via a holder (applicator), as shown in Fig. 14.

Figure 15 shows examples of flange wear reduction effects on overseas railroads. The actual measurement data show that LCF is more effective than on-board oil application to flange and on-ground grease application to the head side of the outer rail, let alone no lubrication.



Fig. 12 Flange wearied wheels



Fig. 13 Side wearied rail

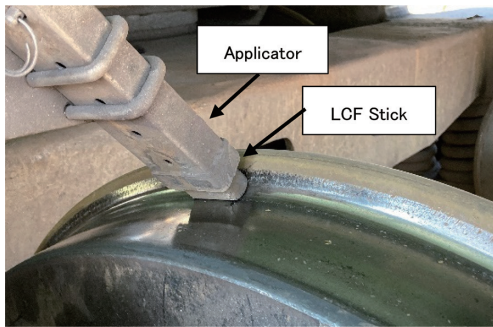


Fig. 14 State of installation LCF and applicator

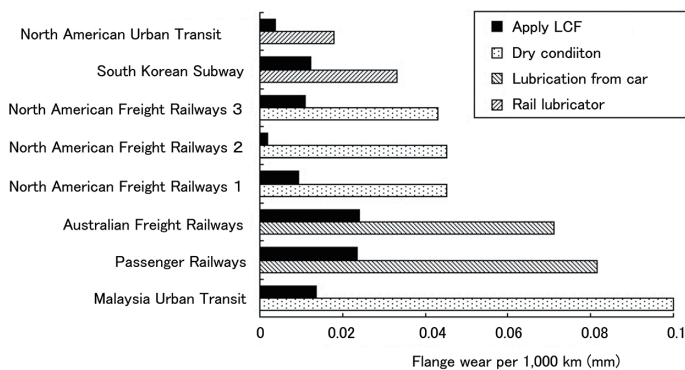


Fig. 15 Actual examples of the effect of reducing wheel flange wear

Internal railroads in steelworks tend to have many curves with relatively small radii under the influence of production equipment arrangement, etc. The weight of the transported goods is also larger than on normal railroads and is more likely to cause flange wear and rail wear. Some of the steelworks use LCF for wear prevention.

In the future, steelworks will be required to operate in consideration of the environment, so it will be desirable to utilize lubricants such as LCF.

#### 4. NSRT's Future Vision

It is feared that the labor shortage in recent years will make it difficult to continue with equipment management. To counter such problems, NSRT aims to deploy the above-mentioned monitoring technologies to both railroad operators and steelworks.

We think that the monitoring data will contribute to the optimization of railroad vehicle and track maintenance and design to meet specific operating environments.

##### 4.1 Vehicle condition monitoring by on-ground measurement

In section 2.4, we described that NSRT employees visit steelworks, collect the data to diagnose the equipment conditions, and supply the data to the steelworks. In the future, we think that condition-based maintenance (CBM) by constant monitoring will be required in place of case-by-case measurement.

Like the wheel load measuring device described in section 2.2, the installation of similar measuring devices in steelworks has the potential to identify internal railroad vehicles in poor condition and prevent vehicle failures that could disrupt the operation of steelworks.

We believe that the combination of the results of vehicle condition monitoring with vehicle inspection and repair histories can lead to the optimization of vehicle maintenance and to the preventive maintenance of vehicles.

##### 4.2 Track condition diagnosis through on-board measurement

We have already begun the development of devices for diagnosing track conditions from the vehicle side and plan to roll them out to both railroad operators and steelworks.

Railroad tracks are generally inspected by appearance inspection through walking patrol and by inspection with measuring devices. As the track conditions change with the vehicle's running, it is preferable to conduct on-board measurements. There is also the issue of securing enough patrolling workers.

Under these circumstances, measuring devices like inertial sensors are mounted on existing railroad vehicles. Devices to diagnose the condition of the tracks are highly effective. We are now working on the development of such devices.

### 5. Conclusions

In this report, we have introduced the deployment of measurement and monitoring technologies and friction modifiers initially to railroad operators and then to steelworks. In view of the declining birthrate and aging population and the changes in the working environment, we intend to deploy monitoring technologies to railroad operators and steelworks, regardless of whether the steelworks belong to the Nippon Steel group, in place of conventional equipment maintenance and management technologies, thereby contributing to the more stable operation of railroads and steelworks.

**References**

- 1) Supervised by Railroads Bureau, Ministry of Transport, and edited by Railway Technical Research Institute: Test Manual for Operation Speed-up of Conventional Railroads and Commentary. 1993
- 2) Koizumi, S.: Advance in Railway Vehicle Technology and Future Prospects Mainly in Relation to Bogie. Nippon Steel & Sumitomo Metal Technical Report. (105), 11–18 (2015)
- 3) Ministry of Land, Infrastructure, Transport and Tourism: Investigation Report on Derailment and Collision Accidents at Nakameguro Station on Hibiya Line of Teito Rapid Transit Authority. 2000
- 4) Supervised by Railroads Bureau, Ministry of Land, Infrastructure, Transport and Tourism, and edited by Japan Railway Rolling Stock and Machinery Association: Commentary on Technical Standards on Railroads (Rolling Stock). 2006



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