# Rail and Contact Line Inspection Technology for Safe and Reliable Railway Traffic

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*OVERVIEW: To help ensure safe, reliable, and comfortable railway service, the inspection of railway line infrastructure is an essential task for railway operators. Hitachi High-Technologies Corporation has long been involved in helping ensure the safety of railway transportation, and is utilizing laser and other technologies to develop methods for inspecting the condition of railway track and overhead contact lines. Hitachi High-Technologies Corporation has also used these technologies to commercialize a railway inspection car that can run alongside commercial services, and can perform railway track and overhead contact line inspections in realtime at Shinkansen speeds. To allow for frequent inspections to be performed, Hitachi High-Technologies Corporation also plans to commercialize systems that can be fitted to operating trains to collect inspection measurements.*

## INTRODUCTION

AS deviation in rail height or warping of the railway track diminish the ride comfort of trains, it is necessary to specify control limits and perform inspection and correction work[1]. Meanwhile, deviation in the position of overhead contact lines are an impediment to reliable operation because they cause abnormal wear on the lines and risk damage to the pantograph[2]. For these reasons, railway operators perform regular railway track and overhead contact line inspections to maintain and improve safety, reliability, and comfort.

In response, Hitachi High-Technologies Corporation has been jointly developing and commercializing railway track and overhead contact line inspection equipment with the Japan Railway companies, including the Railway Technical Research Institute, with the aim of satisfying the long-term needs of railway operators. Hitachi High-Technologies Corporation is helping ensure the safety of railway transportation while also working with its customers to make further improvements.

This article describes technologies for railway track and overhead contact line inspection.

## RAILWAY TRACK INSPECTION TECHNOLOGY

In addition to the precise, high-speed measurement of rails' longitudinal level, alignment, gauge, cross level, and distortion of track, the railway track inspection system commercialized by Hitachi High-Technologies Corporation can also display these measurement results in realtime. A wide range of other optional functions are also available. The following section describes how irregularity in the railway track is measured[1].

### Railway Track Inspection

In the measurement of railway track irregularities, the method used to measure longitudinal level irregularity and alignment irregularity is called the leveling line method (differential method). It involves measuring how far the rail deviates from a fixed length of string stretched along the length of the rail.

Cross level irregularity, meanwhile, is measured using a spirit level and inclinometer (instrument for measuring gradient). Gauge irregularity is determined by using a measuring stick (called a gauge) to measure the gap between the left and right rails (see Fig. 1).

Performing these measurements manually is very inefficient and finding the time to perform measurements over a wide area becomes more difficult as the frequency of trains increases. This has created a need for a more efficient way to perform railway track inspection. In response, railways companies have built special-purpose inspection cars fitted with an inspection system to perform inspections based on the principles described above.

### Principles of Railway Track Inspection

The inspection system installed in the inspection car measures longitudinal level irregularity by using the carbody as the longitudinal reference line and

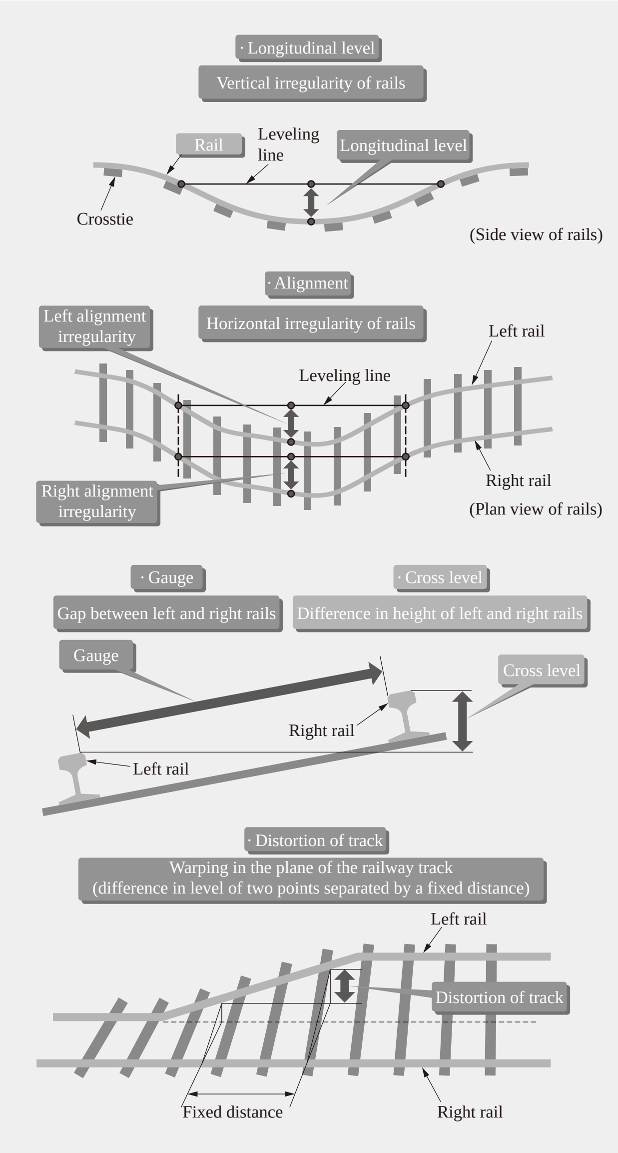



*Fig. 1—Measurements Required for Railway Track Inspection.*
*These figures show the various railway track positions to be measured and inspected.*

attaching sensors to the carbody above each train wheel axle [at three points (axles) for each rail] to obtain the longitudinal level irregularity from the vertical movement of the wheel (see Fig. 2).

The total measurement distance is 10 m and this method is called the 10-m mid-chord offset method, with measurement distances 1 and 2 being 5 m each.

Although measurement of alignment irregularity also uses the carbody as the longitudinal reference line, the train wheels cannot be used to measure this type of railway track irregularity because of the play that exists between the wheel flange and rail. Instead, a special-purpose sensor is required. Both contact and non-contact sensors can be used. Contact sensors work by installing a special measurement wheel on the carbody that comes into direct contact with the inner side of the rail and measures the amount of irregularity. However, the difficulty of achieving accurate measurements using this method at Shinkansen speeds has created a need for non-contact sensors. For these reasons, it is now non-contact sensors that are most commonly used, and Hitachi High-Technologies Corporation has commercialized an optical rail irregularity sensor that works by the optical cutting method(3). The optical rail irregularity sensor directs a band of light from a laser onto the side of the rail and detects the light to determine the amount of irregularity. These sensors are also used to measure gauge irregularity (see Fig. 3).

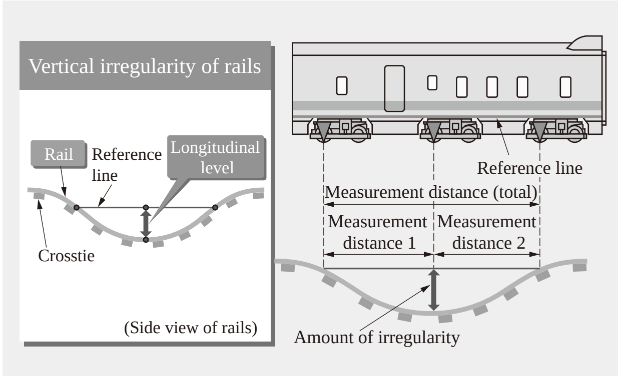



*Fig. 2—Example Use of Sensor to Measure Difference in Longitudinal Level.*
*A system able to satisfy the requirement for automation, and based on the same principles as manual measurement, was implemented using the carbody.*

For cross level measurement, the difference in longitudinal level between the left and right rails is determined by detecting the angle of tilt of the carbody and measuring the separation between the carbody and rail at this time.

## OVERHEAD CONTACT LINE INSPECTION TECHNOLOGY

Overhead contact lines are given a horizontal zigzag pattern to provide a uniform contact with the pantograph.

The overhead contact line inspection system commercialized by Hitachi High-Technologies Corporation can perform fast and accurate measurements of the wear, deviation, and height of the contact line, and can display the results in realtime. A wide range of other optional functions are also available. The following section describes how each measurement is performed (see Fig. 4).

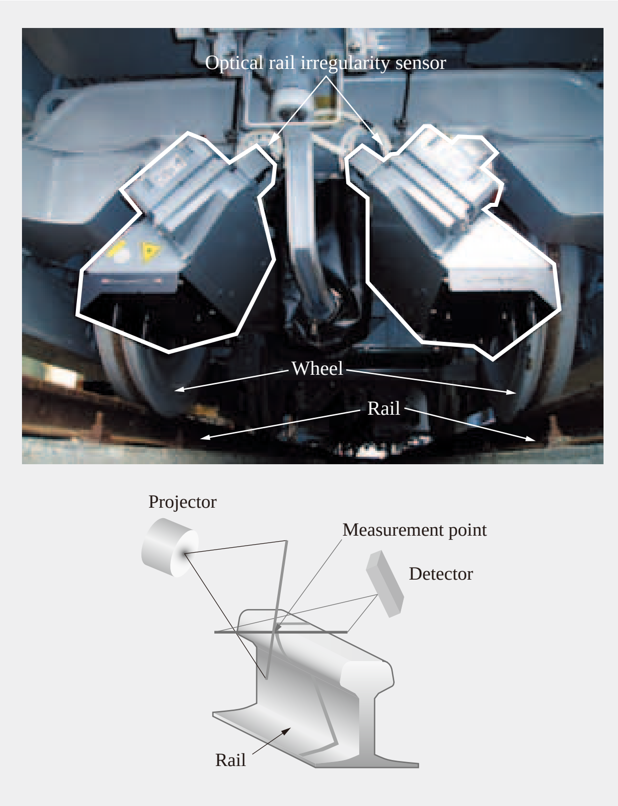



*Fig. 3—Optical Rail Irregularity Sensor Based on Optical Cutting Method and its Principle of Operation.*
*Non-contact sensors are now the most commonly used type because they can provide precise measurements at high speeds.*

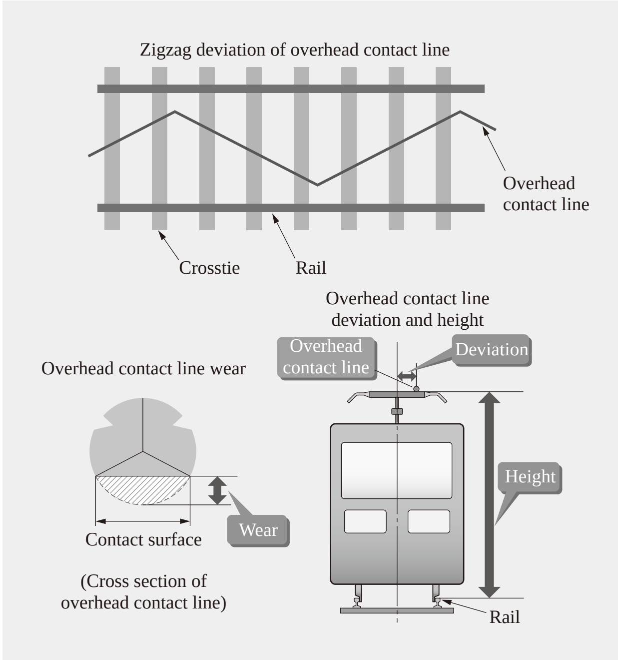



*Fig. 4—Measurements Performed for Overhead Contact Line Inspection.*
*These diagrams give an overview of the required overhead contact line inspection measurements.*

## Contact Line Wear Inspection

The overhead contact lines supply electric power to the rolling stock through direct contact with the pantograph. Wear on the overhead contact line can be divided into mechanical wear caused by rubbing against the pantograph, and electrical wear caused by arcing when the overhead contact line and pantograph become separated. Because of the risk of the overhead contact line snapping if this wear exceeds a certain limit, it is essential that maintenance be done before this limit is reached.

## Contact Line Deviation Inspection

As the overhead contact line is in contact with the pantograph, if this contact is restricted to one particular location on the pantograph, this part of the pantograph will wear down. To prevent wear from being concentrated at a particular location, the supports at each power pole create a horizontal zigzag pattern to ensure a uniform spread of contact with the pantograph. However, if the amount of horizontal zigzag in the overhead contact line exceeds the length of the pantograph, there is a risk of the overhead contact line getting caught on the edge of the pantograph, and this could result in the overhead contact line snapping or a train accident occurring. To prevent this, it is necessary to set a limit on the amount of horizontal zigzag in the overhead contact line, and to conduct inspections to confirm that this limit is not exceeded.

## Height Inspection

Because overhead contact lines expand and contract with seasonal temperature changes, this varies the amount of flexing in the lines. This flexing causes changes in the longitudinal level of the overhead contact lines, and changes in height can cause the pantograph to bounce and become separated. Because separation from the overhead contact line causes electrical wear, as described above, height inspections are also needed.

Pantographs also experience aerodynamic lift depending on the speed of the train. Because this pushes up the overhead contact lines, it is essential that measurements be made under operating conditions.

## Principles of Overhead Contact Line Inspection

As the overhead contact lines are located above the train, factors such as sunlight need to be considered when performing measurements from an inspection

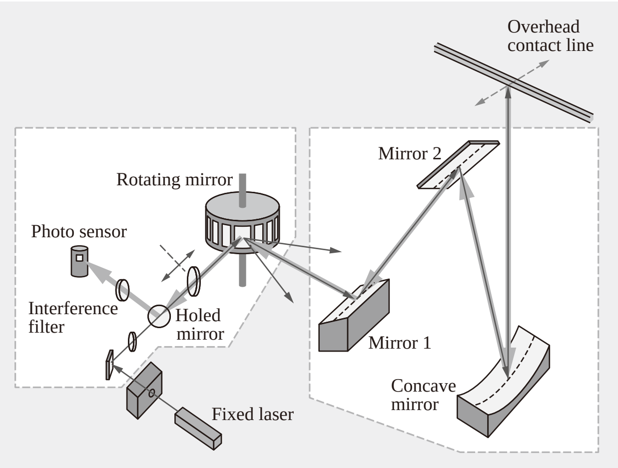



*Fig. 5—Principles of Overhead Contact Line Inspection Measurements.*
*Measurements can be performed with a pitch of 50 mm, even at Shinkansen speeds.*

*Fig. 6—Railway Inspection Car for Shinkansen Lines.*
*Inspection systems fitted on the Doctor Yellow inspection cars used on the Tokaido and Sanyo Shinkansen lines (right) and the inspection car used on the Shinkansen lines operated by the East Japan Railway Company (left).*

car. The overhead contact lines also have a horizontal zigzag pattern, as described earlier, and this means that measurements need to be conducted over a long length of line. To overcome these problems, Hitachi High-Technologies Corporation has commercialized an overhead contact line wear detector[2]. The detector works by using laser light from a point light source that is scanned to the left and right by a rotating mirror and then converted by a concave mirror into a parallel beam that is directed at the contact surface of the overhead contact line. This laser beam reflects off the contact surface and travels back along the same route and through an optical filter to a photo sensor to measure the amount of wear and deviation (see Fig. 5).

Methods used for height measurement include measuring the angle of the main pantograph axle, which indicates the up and down motions of the pantograph, or using a laser beam to measure the height of the underside of the slider plate on the pantograph that contacts the overhead contact line.

## RAILWAY INSPECTION SYSTEM

Hitachi High-Technologies Corporation has commercialized numerous track inspection and overhead contact line inspection systems that use the technologies described above to satisfy the requirements of railway operators. This includes performing inspections using railway inspection cars for the Shinkansen fitted with top-of-the-range systems (see Fig. 6).

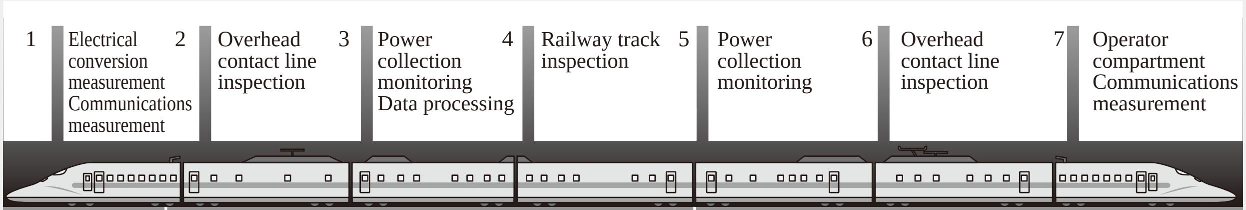
The inspection cars for use on the Tokaido and Sanyo Shinkansen lines are known informally as “Doctor Yellow” and consist of a 7-car configuration. Each car is fitted with a variety of inspection equipment, and most of these are systems in which Hitachi High-Technologies Corporation has had an involvement (see Fig. 7).

The measurements performed by these systems are listed in the bottom half of Fig. 7. A total of 25 different railway track inspection measurements are performed, including noise and axle-box accelerations as well as the main measurements, and these measurements are made at 25-cm intervals. The overhead contact line inspection system, meanwhile, performs a total of 13 measurements at 5-cm intervals. These include the main measurements. Inspection can be performed at speeds similar to those used by regular train services (270 km/h).

## FUTURE DEVELOPMENT

Current practice is to perform regular inspections from special-purpose cars using the inspection technologies described above. However, it is anticipated that frequent inspections will be performed in the future with the aim of making further improvements in inspection efficiency, reliability, and ride comfort.

One requirement that has arisen as a way to perform inspections frequently is to fit the inspection systems to the rolling stock used for commercial service so that measurements can be performed during normal operation. To make this possible, Hitachi High-Technologies Corporation has already commercialized an inertial mid-chord offset track inspection system for railway track inspection, and is working on the commercialization of an overhead




| | Railway track inspection system | Overhead contact line inspection system |
|---|---|---|
| Measurements | (1) Longitudinal level, (2) Alignment, (3) Gauge, (4) Cross level, (5) Distortion of track, (6) Other measurements | (1) Overhead contact line wear, (2) Overhead contact line deviation, (3) Overhead contact line height, (4) Other measurements |
| Measurement interval | 25 cm | 5 cm |

*Fig. 7—Configuration of Doctor Yellow Cars.*
*These inspection cars for use on Shinkansen lines provide world-class high-speed, realtime processing. Because they use cars with the same dual-bogie configuration as the actual Shinkansen, railway track inspection uses a laser beam rather than the carbody as a reference for measurements (dual-bogie method).*

contact line inspection system suitable for installation on standard rolling stock.

The intention is to reduce the size of the overhead contact line inspection system for standard rolling stock by modifying the measurement methods and making major changes to the components used by the system.

The inertial mid-chord offset track inspection system replaces the differential measurement method used in the railway inspection car and other applications with inertial mid-chord offset measurement, a form of inertial measurement. Inertial measurement[(4)] utilizes a basic principle of mechanics (that irregularity can be obtained by twice integrating acceleration) to obtain irregularity from acceleration, and mid-chord offset measurement was developed to produce the same output as the previous system by performing a calculation in which the characteristics of the 10-m mid-chord offset method are combined with the inertial measurement method[(5)] (see Fig. 8).

This method saves space by replacing the large number of detectors required for the measurements described earlier with just three detectors and combining them into a single unit so that they can be installed on standard rolling stock.

A bogie-mounted version of the inertial mid-chord offset track inspection system has already been implemented, and a version for mounting on the carbody is currently undergoing field evaluations in preparation for commercial operation. These systems have been well received by customers (see Fig. 9).

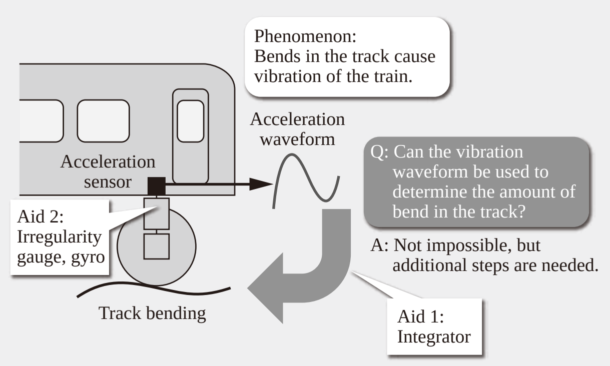



*Fig. 8—Principle of Inertial Mid-chord Offset Track Measurement.*
*The system integrates acceleration measurements to determine irregularity.*

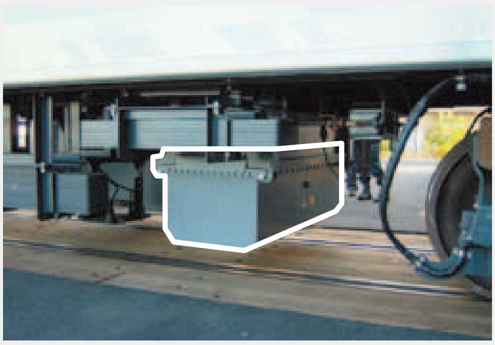


*Fig. 9—Inertial Mid-chord Offset Track Measurement System for Mounting on Carbody.*
*This version of the inertial mid-chord offset track inspection system intended for mounting on the carbody is currently undergoing field evaluations.*

Once these field evaluations have been completed, it is anticipated that the systems will help improve the frequency of inspection through their use on major railway lines serving large cities and elsewhere.

## CONCLUSIONS

This article has described technologies for railway track and overhead contact line inspection supplied by Hitachi High-Technologies Corporation, together with the inspections performed by railway operators to ensure safe, reliable, and comfortable railway service.

By providing the market with even better products in the future, Hitachi High-Technologies Corporation intends to continue making a contribution to the development of comfortable railway service that is safe and highly reliable.

Finally, the authors would also like to express their deepest thanks to everyone involved for their advice and assistance.

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