Aiming at World-leading Maintenance Technology

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Introduction

This article explains some of the maintenance-related research conducted at the Technical Center in the Research and Development Center of JR East Group. In particular, I would like to explain some themes related to 'interface technologies' into which we have been putting a great deal of effort recently. The main interface technologies are found at wheel/rail, pantograph/catenary wire, and switches/crossover.

R&D Aiming at Innovation in Maintenance

JR East operates more than 12,000 train services each day on both shinkansen lines and conventional lines. To keep these trains running, there is a huge amount of infrastructure that must be maintained in addition to rolling stock. Figure 1 shows the breakdown of current rolling stock and infrastructure. There are more than 13,000 pieces of rolling stock, 5,500 km of electrified sections and almost 12,000 km of track. Some of the infrastructure such as tunnels and bridges, has been in use for just 30 or 40 years but some parts are more than 100 years old. JR East is required to perform maintenance in a diverse number of fields, including mechanical, electrical, civil engineering, etc., on a variety of items built in various periods since the first railways in Japan. It is the responsibility of my Technical Center to conduct research that supports JR East's maintenance staff in keeping this huge railway business operating smoothly. The proportion of maintenance costs in JR East's business expenses as well as the proportion of maintenance engineers in JR East's total labour force are both nearly 30%, clearly a relatively large proportion. Obviously maintenance costs are a very heavy burden for railway operators and any technical advances in railway maintenance would play a major role in cost reduction. Figure 2 shows the main themes in maintenance today. Reduction of maintenance costs is a major item in leading to better competitiveness of railways, but creating a better maintenance system structure that would lead to better safety and business stability is also important. In addition, another major theme is the number of people performing maintenance and the declining workforce in Japan. These themes are important in maintaining a competitive business and creating a railway that is kind to the environment and people.

Our Technical Center undertakes R&D based on these important considerations. First, our research aims to create innovation in maintenance that must cut costs, improve reliability, and support on-site maintenance (Fig. 3). Second, our research aims to strengthen the fundamental concepts of our railway maintenance and establishing world-leading evaluation, maintenance and management techniques. Both these aims come within the premise of the *Frontier 21* plan forming the medium-term business concept for the JR East group.

Our research approach to cutting maintenance costs, improving reliability, and supporting on-site maintenance is to develop systems for maintaining rolling stock and infrastructure that minimize the amount of manual work. As a consequence, a major thrust of our R&D is developing new intelligent technologies for application to inspection and work procedures. In addition to analyzing various older themes in a variety of technical fields, such as rolling stock, infrastructure, power supply, etc., we are also putting a great deal of emphasis on maximizing the system as a whole based on the concept of interfaces between different technologies.

Our Technical Center is staffed by specialist engineers with experience in a variety of technical fields who work together on research themes related to

Figure 1 Current Rolling Stock and Infrastructure

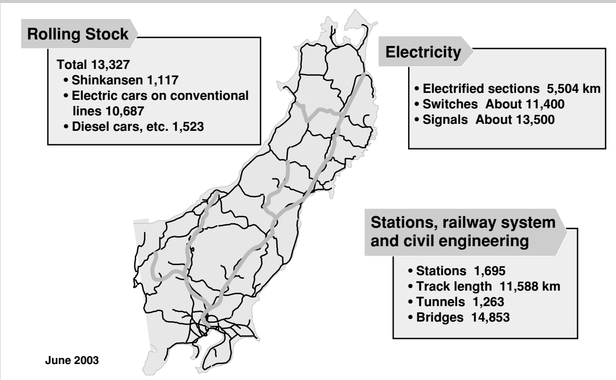


Figure 2 Maintenance Themes

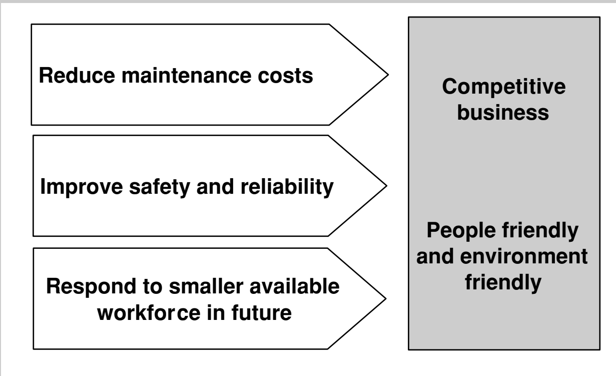


Figure 3 Roles of Technical Center

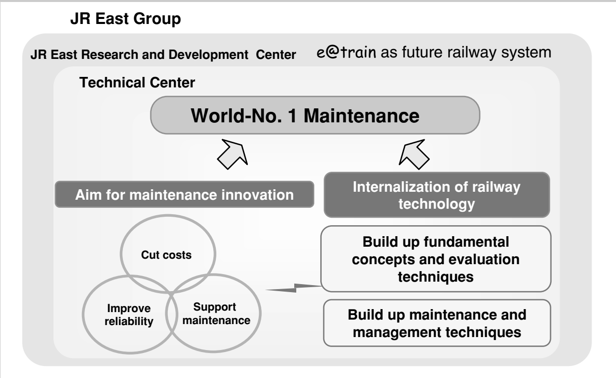


Figure 4 Fatigue-induced Shelling at Rail Head

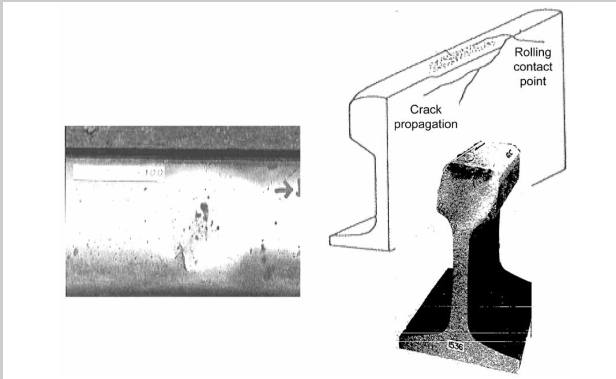


Photo 1: Corrugation wear along rolling surface of rail head (JR East)

Photo 2: Wear on inside edge of outside rail on curve (JR East)

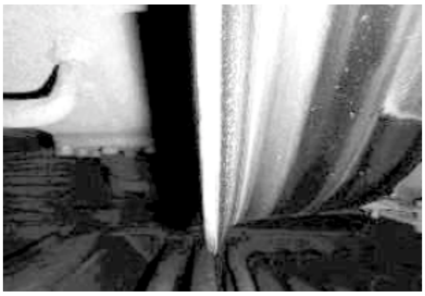


Photo 3: Rectangular wear at inside arc profile of wheel flange (JR East)

interface technologies while realizing the great importance of producing results that are applicable to actual maintenance.

Wheel and Rail

The point of contact between the wheel and rail has been a fundamental issue in all previous railway work but there are still a number of major issues that remain to be tackled. A good example is wheel squeal that occurs on sharply curved sections of track due to the contact surfaces between the wheels and rails. Moreover, corrugation along the rolling surface of the rail head (Photo 1) have a major negative impact on passenger ride comfort as well as on rail and carriage maintenance. Other examples are wear occurring on the inside edge of the outside rail on a curve (Photo 2), and heavy wear causing a change in the profile of the inside arc of wheel flange (Photo 3). Another example is fatigue-induced cracking at the rail head called shelling (Fig. 4), which is one of the major reasons for replacing rails. If we could understand and solve these problems occurring in wheels and rails, the amount of maintenance required would be greatly reduced, having a major impact on cost reduction.

Among the annual maintenance costs of replacing carriage parts, the expense of repairing wheels is quite high but the cost of replacing rails is close to four times that of wheel repairs. Some of our research aims to optimize the entire system by cutting rail replacement costs.

Optimizing contact shapes

The tread of a wheel on conventional carriages is in the form of a series of arcs that are designed to prevent derailing. In our research, we used wear tests to examine the variation in wheel tread wear. In addition to developing a new wheel tread profile, we discovered a wear profile that provides better stability in actual use. On the other hand, for the rail cross-section shape we tested two rails with changes to the shape of the rail head. Running wear tests using different combinations of these wheels and rails produced an optimum rail design suffering much less wear. At the moment, we are still performing quantitative measurements of rail wear under various severe test conditions.

Lubrication

Figure 5 shows some of the problems that occur on rails from curves over time. Since the wheel tread contacts the surfaces of the heads of the inner and outer rails at different positions, there is clearly different wear on the inner and outer rails of curves. We are developing rail-head lubrication to solve these problems. Currently, each time a train passes through a difficult curve, a greasing mechanism mounted on the track lubricates the inner rail head to reduce wear (Photo 4). However, this method has problems with

Figure 5 Optimizing Wheel and Rail Contact

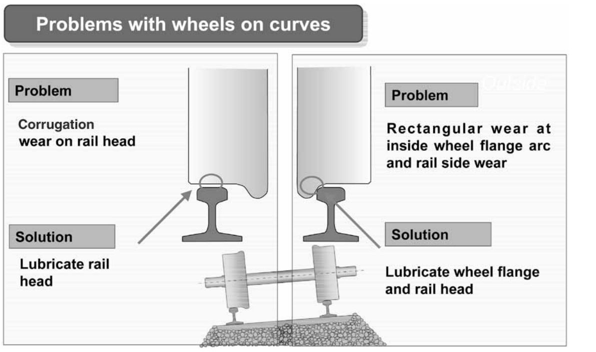
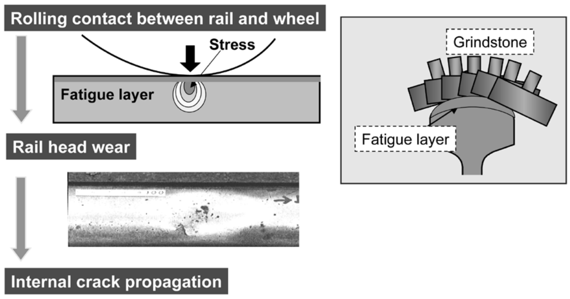


Figure 6 Managing Shelling by Rail Grinding



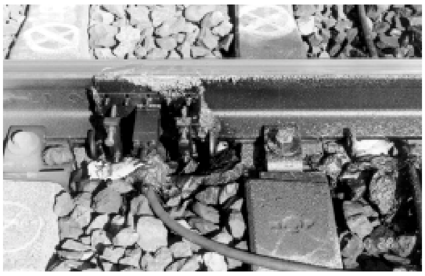


Photo 4: Track-mounted greasing mechanism (JR East)

Photo 5: Bogie-mounted greasing mechanism (JR East)

wheel slip, and sliding, etc., and also with contamination such as grit sticking to the rail and causing more wear. As a result, it can only be used on some sections. Future methods for lubricating the inner rail will have to be easy to use, environment friendly and minimize the wear factor while reducing corrugation wear along the rail head as well as wear caused by lateral thrust. Conversely, they will have to secure sufficient adhesion between the wheels and rail.

On the other hand, for the outer rail, a greasing mechanism installed on the ground lubricates the inside edge of the rail while another greasing mechanism mounted on the bogie (Photo 5) of the carriage lubricates the inside wheel flange each time a train passes through the curve by spraying lubricant onto the face of the flange running along the inside of the outer rail. In this case too, there are problems with contaminants such as grit sticking to the lubricated rail as well as problems with wheel slip, etc. The new lubricant developed for this purpose is similar to current lubricants but is more effective at reducing the wear factor while being water-soluble to reduce any environmental impact. In addition, we are also looking at developing greasing mechanisms that apply a constant coat of lubricant reliably.

Rail surface fatigue

When a wheel runs repeatedly over a rail as shown in Figure 6, a fatigue layer is formed the point of rolling contact between the wheel and the rail. As the fatigue leads to rail defects, the surface of the rail starts shelling, then metal scales form internally. In the serious cases, the rail may actually break. When shelling is discovered the usual procedure is to replace the rail, but if the damage is not too serious it is possible to grind the rail surface and remove the wear. This procedure can be quite effective and is expected to play a large role in cutting costs and preventing accidents. An important R&D theme is assessing when to perform grinding and how to perform it. Another aspect is analyzing data on the weight and speed of different types of passing trains as well as on the track geometry in relation to the occurrence of shelling. One method is to intentionally generate shelling using a rolling tester and then to confirm the effect of grinding on the fatigue layer, the best frequency for grinding and the required amount of grinding.

Pantograph and Catenary Wire

Figure 7 shows the relationship between the catenary and the pantograph. The pantograph slip plates press directly on the catenary trolley wire to collect current. To keep the trolley wire horizontally flat with no sag, it is hung on hanger wires from a messenger wire running in a series of long arcs between support structures such as poles and beams, etc. On the other side of the interface, the pantograph is constructed of an arm and a collector shoe or wing carrying the slip plates for collecting the current. The figure shows a modern single-arm design. If the slip plates separate from the trolley wire, arcing damage can occur and there are also problems with frictional wear due to mechanical abrasion as the slip plates run along the wire at high speed. A further problem is the temporary loss of power when the slip plates separate from the trolley wire. In terms of maintenance, the main work involves managing wear

Figure 7 Pantograph Contact

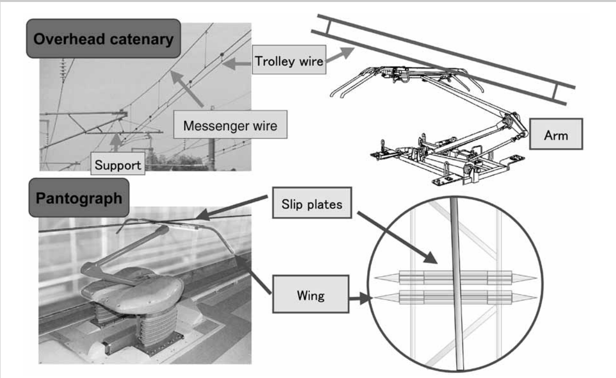
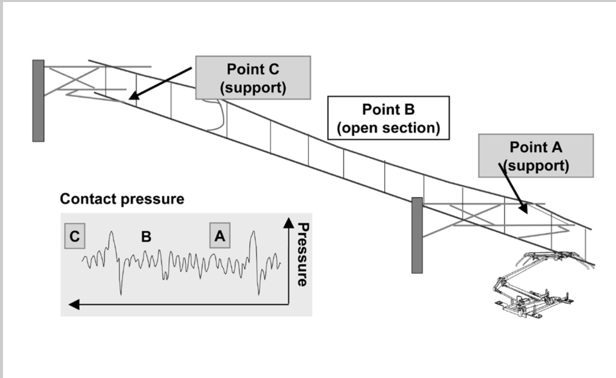


Figure 8 Changes in Pantograph Contact Pressure



occurring on the catenary trolley wire and pantograph slip plates (Photo 6). The most difficult and most costly work involves replacing the trolley wire. For example, replacing the trolley on the Yamanote Line in Tokyo has to be performed once every 6 or 7 years and in terms of annual maintenance costs, trolley wire repairs are about 20 times more expensive than slip plate repairs. Consequently, our research at this interface is endeavouring to cut the costs of trolley wire maintenance.

Contact measurement pressure

As shown in Figure 8, the pressure of the pantograph slip plates on the trolley wire fluctuates greatly as the train runs along the track. The highest pressure occurs at the catenary supports (points A and C) and it is also reasonable to expect large variations in the pressure at locations where there are faults such as disconnected hangers, etc. As a consequence, we are proceeding with research into a system that can be used to measure the contact pressure automatically for troubleshooting the catenary.

We have taken the first step in developing a system for measuring contact pressure automatically by installing battery-powered telemetry test equipment on the roof of a Series E3 shinkansen carriage (Photo 7). This sends measurement data by radio transmission to in-carriage equipment for subsequent data processing. We have performed two test runs between Sendai and Kitakami in January and November 2002 and Figure 9 shows an example of some of the obtained data.

Looking at this chart, we can see there are particular places where the contact pressure drops, in other words places, where the pantograph separates from the trolley wire. In addition, there also points where the contact pressure spikes quite suddenly. These might be explained by the so-called 'overlap section' where a terminating wire runs in parallel for several meters with a beginning one in several meters. Clearly, by using this type of contact pressure measurement system we can quickly get an understanding of the condition of the catenary and we

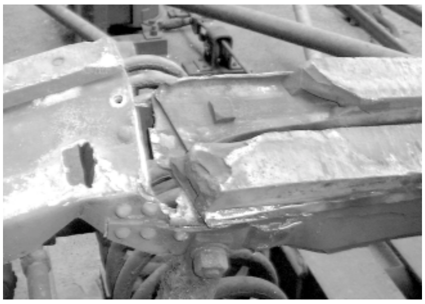


Photo 6: Missing and damaged slip plates (JR East)

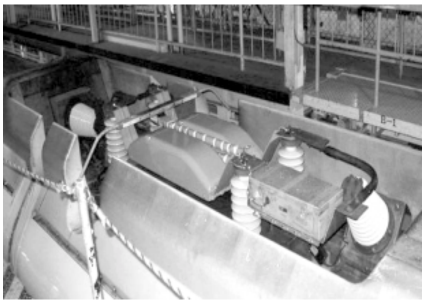


Photo 7: Catenary measuring equipment on roof of Series E3 shinkansen test train (JR East)

Figure 9 Pantograph Contact Pressure Data

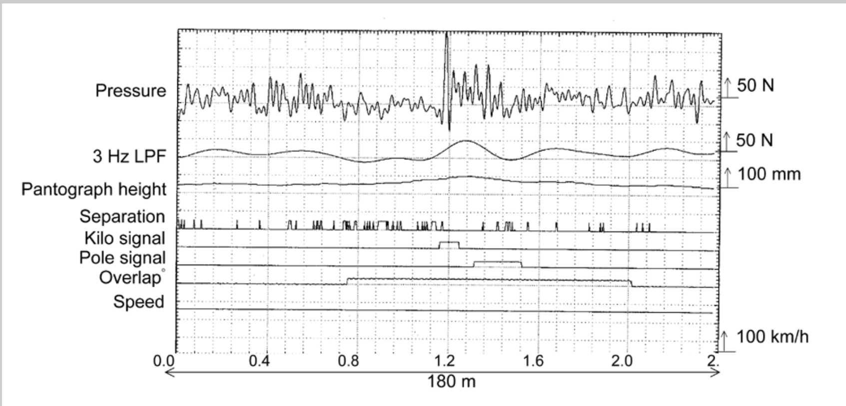
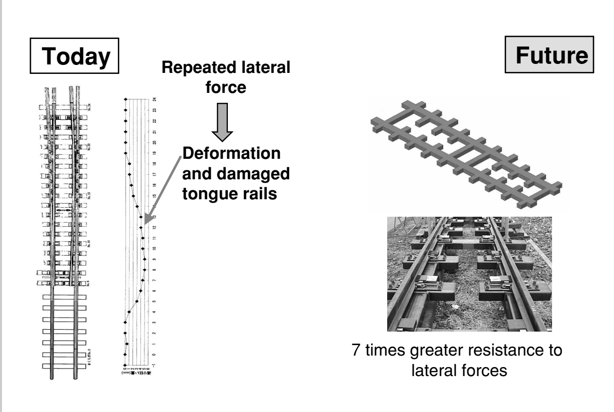


Photo 8: Deformed main rail next to switch tongue rail (JR East)

Figure 10 Grid Sleeper Track at Switches



believe that this will play a major role in cutting the catenary maintenance costs.

Although the system is already producing results, there are still some potential areas for improvement; in the future we intend to estimate of the aerodynamic lift force during running to obtain an even more accurate contact pressure.

The future development involves testing the basic characteristics of the measurement system using optical sensors, installing the system on JR East's inspection car, testing the installation with test runs and diagnosing the catenary using the obtained contact pressure data.

Next-generation Crossovers and Switches

Current problems

The direction of a train passing through points is controlled by the movement of the tongue rails and the structure can be extremely complex, which is a weak point in these types of large ground infrastructure. Certain points error can result from poor mating between the tongue rail and main rail due to deformation like that shown in Photo 8.

Another weakness of points is that their operation can easily be disrupted. The presence of a foreign object such as a ballast stone between the main rail and tongue may leave the tip of the rail open, causing a points error.

Moreover, the signal failure tends to occur due to the complicated crossover mechanism. Generally, the left and right rails are isolated to detect the position of a train. When a train comes, the left and right rails are shorted electrically with a wheel and an axle, and detect a train by a track circuit.

However, sometimes even when there is no train coming, slippage of the left and right tongue rails may cause contact between the switch bar and switch adjuster rod creating a short.

Moreover, the presence of an electrically conductive foreign object, such as an empty metal can may cause a short at the isolator, forcing the signal to remain at red and causing disruption to operations.

In addition, the maintenance of points requires tremendous manual labour. Typical examples might be lubrication of points or adjusting the switch bar mechanism.

We are currently involved in R&D into next-generation points and switches for the 21st century. Our development basis is fault-free and low-maintenance structures.

Increased rigidity by grid sleepers

Points receive tremendous and repeated lateral forces each time a train passes through them. As a result, as shown in Figure 10, the sleepers tend to be displaced horizontally, creating changes in the track geometry. To prevent this, we have developed and are using so-called grid sleeper track in which the sleepers run longitudinally bound by crossties. This structure has much greater durability and is able to resists changes in track geometry.

Improved base plate for more reliable switching motion

Since the tongue rail has a sliding base plate, the main rail can only be secured by a tie fastening on the outer side of the rail. With our new design, the lower height of the tongue rail permits use of a higher base plate (Fig. 11). As a result, the main rail can also be gripped from below. In other words, the main rail is securely fastened on both sides, suppressing rail slippage. In addition, foreign objects can fall into a small space between the tongue rail and main rail, reducing the possibility of switching errors. Finally, since it uses a bearing base plate, lubrication is unnecessary.

Innovative switch machine

Theoretically, we think it is possible to achieve a 75% weight reduction in this very heavy piece of equipment from 400 kg down to around 96 kg; we are also achieving a 66% reduction in the area of the switch drive mechanism. These advances have been achieved by using lightweight aluminium alloys for the switching frame as well as small high-performance servomotors and a new link design.

With this development, the status of these new switches can be easily confirmed by

Figure 11 Improvement of Base Plate

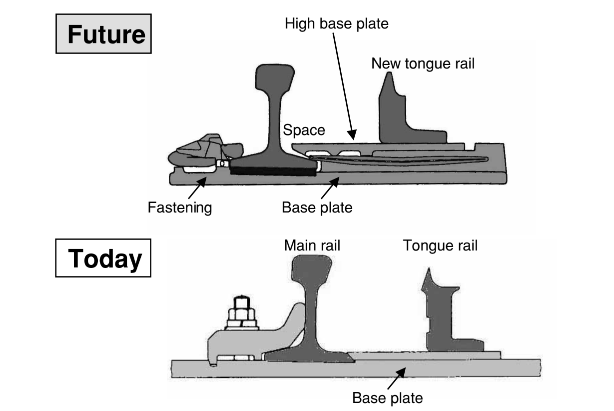
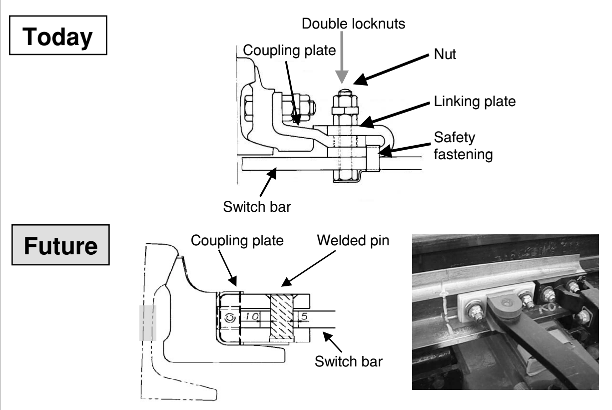


Figure 12 Pin Coupling at Switch Bar



anybody using a number of lit LEDs. Furthermore, the switch controller has been changed from the previous type of relay circuit to an electronic circuit with data transmission using optical fibre cables. As a result, problems with the relay contacts are eliminated by digitization that also permits remote monitoring of faults. In addition, the main body of the older switch design was used for mounting other ancillary equipment, increasing the installation footprint area and making it difficult to secure a switch to a sleeper using a multiple tie tamper. Similarly, any shortage in the amount of ballast stone could easily lead to movement and deformation of the track geometry. The smaller lighter simplified structure makes it possible to install the entire switch body and peripheral equipment on a single sleeper, permitting much easier mounting using multiple tie tamper and ensuring sufficient ballasting.

Improved switch ancillary devices

As I explained previously, currently there is the problem with shorting if a conductive foreign object such as an empty metal can falls centrally between the rails. This has been solved relatively simply by installing insulators at two locations, greatly reducing the incidence of track shorts. We have made other revisions but probably the most effective in simplifying difficult work has been lightening the weight. As a consequence, the ancillary equipment can be installed at the work preparation stage and coarse adjustments made at the same time. This means that the on-track work time can be reduced while cutting the number of difficult operations too (Fig. 12).

Our above-mentioned next-generation points have been installed in Omiya Station yard on the outskirts of Tokyo since February 2002. We hope this encouraging result will soon lead to their full commercial introduction throughout Japan and help reduce track-related accidents and maintenance costs.

Summary

As described in this article, our Technical Center is pursuing R&D in a diverse range of fields related to solving maintenance problems especially at the interface between different technologies. But our R&D is not just related to technology interfaces and we are working hard to innovate railway maintenance in many other areas. As other articles in this issue of *JRTR* have mentioned, this work requires efficient introduction of world-leading, advanced and new technologies. To this end, the Technical Center is also conducting joint research with railway laboratories around the world, universities, rolling-stock manufacturers, other industries, etc. This type of R&D can only be conducted in concert with other experts in the field and we are actively considering how to create new information systems for sharing our results with others. I hope that readers of this article around the world will be encouraged to contact and work with us on ways to improve the world's railways. ■

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Mr Inazu is Director of the Technical Center in the Research and Development Center of JR East Group. He joined JNR in 1973 after graduating in engineering from Tohoku University. He has held various posts in the operations and rolling stock departments of JR East.