Development of a Track Monitoring System Installed on Trains in Operation and Future Prospects for the System



Ryohei Kasai* Hideyuki Yahagi* Takayuki Onodera*

The track monitoring system installed on trains in operation consists of a device that measures track irregularity and a device that detects failure of track materials. Tests of the system installed on the Keihin-Tohoku Line started in May 2013 and are still ongoing. The system can perceive changes in track irregularity and detect with high probability missing ordinary rail fastenings. As the final goal, we aim to introduce the track monitoring system to our lines in the greater Tokyo area as well as JR East as a whole.

●Keywords: Track monitoring, Inspection, Track irregularity, Track material

1 Introduction

Development started on a track monitoring system starting in around 2008. We were able to install a prototype on the MUE-Train multi-purpose test train and conduct running tests and improvement of the system up to the end of fiscal 2012. Results of the tests showed that we successfully met the intended objectives. Since May 2013, we have been carrying out final research and development using the system installed on a train in operation with an aim of putting the system into practical use.

This article will cover the tests using the system on a train in operation and future perspectives for the track monitoring system.

2 Overview of the Track Monitoring System

The system consists of a track irregularity measuring device and a track material monitoring device. The former measures track irregularity, and the latter measures the condition of track material such as rail fasteners. Existing technologies are used for the principle of measurement. For the track irregularity measuring device, we used the inertial mid-chord offset method (IMOM) developed by the Railway Technology Research Institute and introduced to the Kyushu Shinkansen, and for the track material monitoring system, we used three-dimensional range image recording and analysis technology used in various industries.

Many new means have been thought out for the system configuration and arrangement of the components, even though the principle of measurement cannot be called innovative. Such new means were needed because there are severe restrictions in space and height of the components to be accommodated under the floor of the train, and some components had to be installed to places not optimal for measurement due to the presence of existing underfloor devices. We also took countermeasures against vibration of running trains and lateral deviation on curves.

For the principle of the system and the details of the tests on the MUE-Train omitted in this article, please see the reference.[1)]

3 Efforts in Running Tests Using a Train in Operation

When installing the system on a train in operation, we tried to choose a train where the system would not interfere with existing underfloor devices. But we could find no train where installation space could be secured, so we chose a trailer on which we could install the system with minimum relocation of underfloor devices. More specifically, we decided to install the whole system on car No. 9 (series E233-1209) of trainset No. 109 of the Urawa Electric Railcar Depot, which was planned to enter the depot for equipment maintenance. This was done so as not to affect trains in operation. Fig. 1 and 2 shows the installed system.

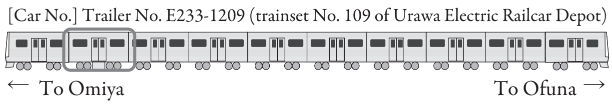

Fig. 1 Trainset with the System Installed

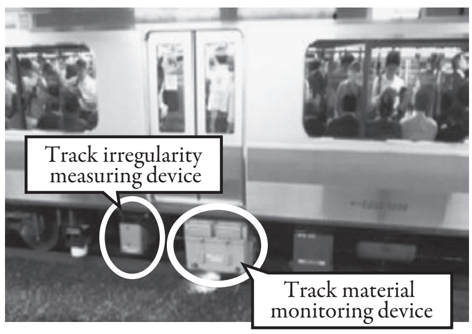

Fig. 2 Track Monitoring System for Trains in Operation (System in Use)

After conducting procedures such as car design and design check required by the Railway Business Act, we modified the car and installed the monitoring device in mid April of 2013.

We also developed a mechanism for the measuring device that allows fully automatic measurement. In running tests on the MUE-Train so far, we adopted a mechanism where the

*Technical Center, Research and Development Center of JR East Group

measurement conditions were preset to the onboard device via radio transmission based on the scheduled test run timetable, and measurement started after the power was turned on wirelessly at the start of running.

In contrast, trains in operation run on different sections based on their operation for the day (Fig. 3), and scheduled operation may be changed in operation disruptions. We therefore have to constantly identify the real-time train location and other information to set the measurement conditions to the onboard device without fail. That was a very difficult requirement to meet.

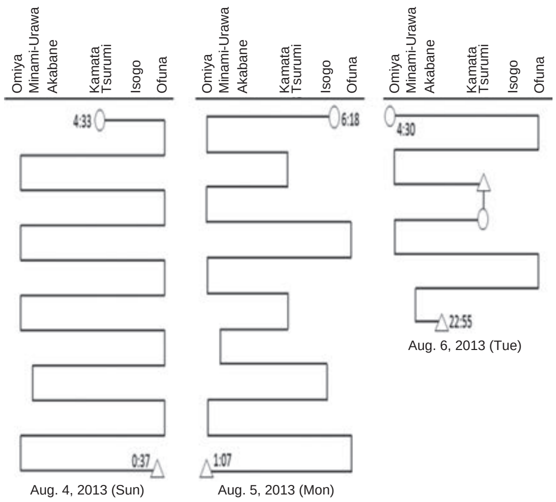

Fig. 3 Example of Train Operation

We therefore added a fully automatic measurement mechanism utilizing data depots (Fig. 4) used as in measuring with vehicles such as the East-i inspection train. Specifically, the system identified the current line and location by detecting the data depots installed along track and started measurement, as is shown in Fig. 5. Using data depots, we were able to develop a fully automatic measurement system at a relatively low cost. However, it has a problem in that there are some sections where measurement cannot be performed due to the difficulty in idenifying the exact location of the train before and after a turn-back station.

(left: onboard terminal, right: wayside terminal)

Fig. 4 Data Depot System

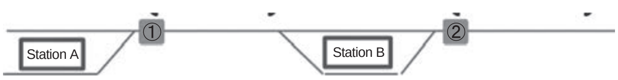

Fig. 5 Location of the Depot where Measurement Starts

4 Results of Running Tests on Keihin-Tohoku and Negishi Lines

At the start of the running tests, some troubles including initial failures of devices occurred. But those were within expectations, and after that, the system has been working stably. The total kilometerage covered up to the end of February 2014 reached 119,200 km (Fig. 6), and no major failures have occurred up to now.

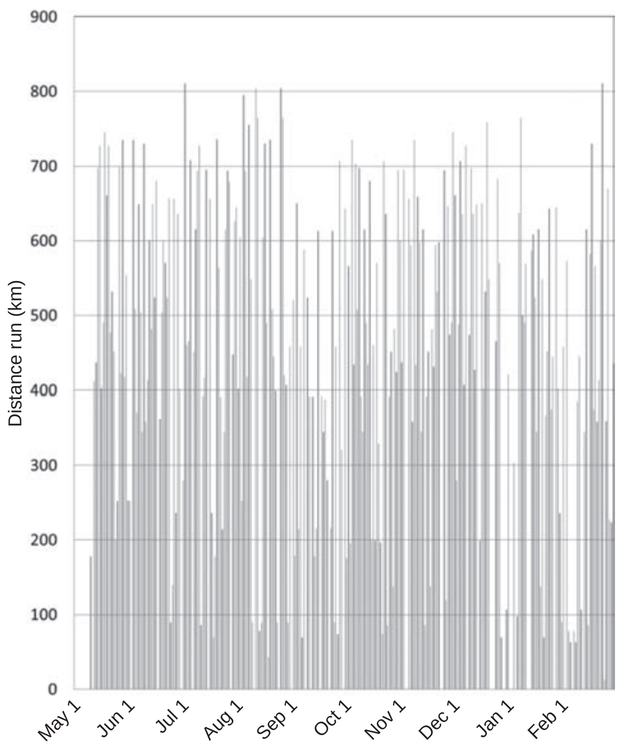

Fig. 6 Distance Run in Kilometers per Day

4.1 Status of Track Irregularity Measuring Device

As the track irregularity measuring device constantly performs measurement while running, we are able to collect a huge amount of data. Fig. 7 shows a comparison with measurement data by the East-i inspection train.

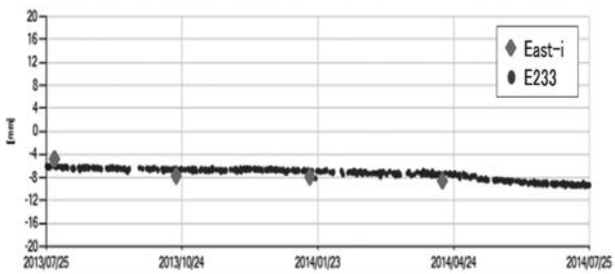

Fig. 7 Example of Frequent Measurement of Track Irregularity with Trains in Operation

The system can precisely catch changes in track irregularity that could not be recognized in the conventional measurement cycle using a track inspection car. Details of how measurement data is utilized can be found in the article "Development of a Technique to Predict Track Irregularity by Analyzing Frequently Obtained Data" in this issue of the JR East Technical Report. Fig. 8 and 9 are some examples of change in track irregularity, with Fig. 8 showing change before and after repair work using a large machine (multiple tie tamper) and Fig. 9 change before and after manual repair work using a tie tamper. Those proved that the difference in repair effects, which before could be explained only empirically, can be clearly confirmed with quantitative values.

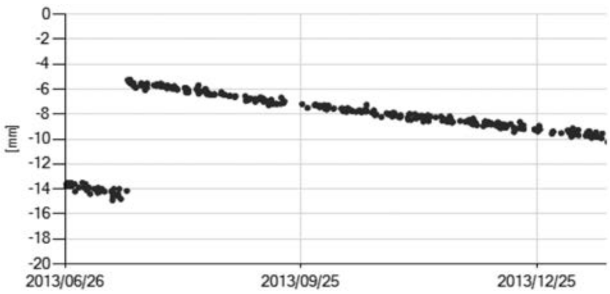

Fig. 8 Change Before and After Repair Work Using Multiple Tie Tamper

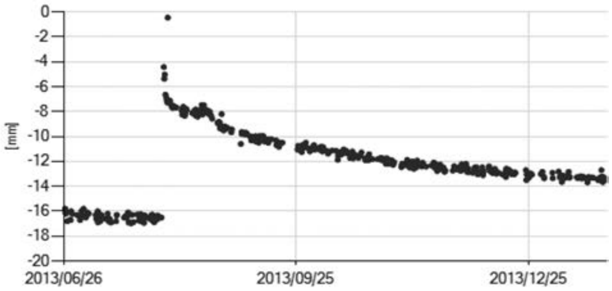

Fig. 9 Change Before and After Manual Repair Work Using Tie Tamper

4.2 Status of Track Material Monitoring Device

The track material monitoring device is working smoothly too. However, the frequency of measurement is now around once a week because we have to retrieve the data by manually replacing the recorder (HDD) as the amount of three-dimensional range image data the device records has reached a level even the latest transfer technology cannot handle. Fig. 10 shows an example of automatic detection of a missing rail fastener and Fig. 11 an example of automatic detection of a missing fish bolt.

The track material monitoring device could not provide us with satisfactory data immediately at the start of tests. But, as a result of repeated improvement of the image data analysis method using the measurement data, the device today can detect missing ordinary rail fasteners with very high probability.

Fig. 10 Image of Missing Rail Fastener

Fig. 11 Image of Missing Fish Bolt

4.3 Status of Real-time Measurement (Detection of Abnormalities and Delivery of Information)

Both the track irregularity measuring device and the track material monitoring device have a real-time measurement function where information of any abnormality detected is immediately and automatically transmitted. However, we found practical use of this function difficult due to many issues that need to be overcome.

With the track irregularity measuring device, incidents where the laser beam did not reflect (a shortcoming of laser beam-based measurement) randomly occurred, making judgment of misdetection or abnormal values impossible. However, we have not been able to find a way to prevent that. In fact, the theoretically impossible values automatically delivered in the running tests were all misdetection. So, if we introduce the device as-is, worksites involved will be overwhelmed by such misdetection.

On the other hand, the track material monitoring device has a mechanism where recorded image data is immediately analyzed to detect abnormalities such as missing fish bolts. Due to image processing capacity reasons, the device performs analysis only when an image of a fishplate is recorded at points registered in advance as joints. Thus, the device omits analysis even if a fish bolt is actually missing, for example, if the point recorded by the device is offset from the intended location. The device also needs some time for analyzing images, so it is difficult to analyze all fish bolts in cases where many short rails are joined in series. That also could lead to overlooking of missing fish bolts.

In light of those issues, we will seek a way to use both devices as real-time measuring devices having a function where only clear abnormities are notified of, rather than having a function where all abnormalities are detected and notified of.

5 Unlimited Possibilities Brought about by Frequently Data Collected

The track irregularity measuring device collects all data while running. Immediately after starting the running test, we were puzzled what to do with such a large volume of data accumulated daily. But, in analyzing that data, we saw unlimited possibilities for utilizing data collected frequently.

First, with data collected frequently, we can have a sufficient amount of data necessary for analysis, even when data including attempted measurements that failed and measurement errors such as misdetection are excluded. Accepting measurement errors leads to easing of conditions for operating devices. During development, there were failures of the laser beam in heavy rain, errors of measurement points due to deviation of pulse signals of the tachometer generator caused by slight slip or spin of the wheels, and other problems. Conventionally, we would make improvements to the device to solve those problems, but we were able to come up with applicational solutions without mechanical improvement by avoiding the use of data that included errors.

We also proved that measurement errors of the measuring devices could be eliminated with very high probability by utilizing a statistical method.

Those results suggest the possibility of significant alleviation of the need for high measurement accuracy of the devices. The current system has devices using two types of measurement principles to make up for lowered measurement accuracy when running at low speed. However, there is a possibility that the data of devices using just one type of measurement principle could secure sufficient accuracy.

If measurement can be done with the devices using just one type of measurement principle, costs can be reduced and restrictions in the space for the system installation will be drastically eased. That will lead to an increase in the type of cars the system can be installed on.

6 Future Prospects

As the running tests on the Keihin-Tohoku and Negishi lines are showing favorable results, we will install the track monitoring system on a car of one trainset each for the Chuo Line and Yamanote Line by the end of March 2015, with an eye to full-scale introduction. After that, we are planning to further install the system to trains for lines in the greater Tokyo area shown in Fig. 12.

Fig. 12 Image of Introduction of System to Greater Tokyo Area

At the same time, in order to accommodate the system within the limited space under the floor of the cars of regional inter-city lines, we are developing a plan to introduce the system without some of the functions of the system developed in this project (Fig. 13).

As the number of residents along and users of regional local lines decrease, it will be imperative for us to introduce the maintenance management approach using the measurement data collected frequently by trains in operation if we are to sustain those lines. Thus, we will narrow down items to be measured and develop a more compact and lower-cost system that can be installed on cars with smaller underfloor space so as to allow the system's introduction at an early date (Fig. 13).

We are aiming to introduce the track monitoring system to the whole operation area of JR East as our final goal.

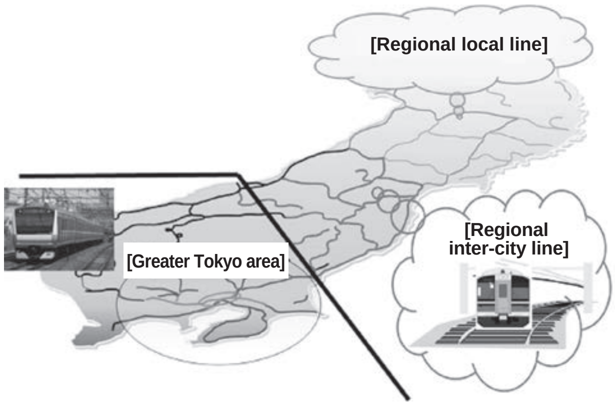

Fig. 13 Image of Introduction of Track Monitoring System

Reference:

1) Ryou Terashima, Hiroyuki Matsuda, Mitsunobu Takikawa, Masanobu Kozeki, "Development of Track Monitoring Systems: Development of Prototypes for Trains in Operation and Running Tests Using a Test Train", *JR East Technical Review* No. 22 (Spring 2012): 11 - 14