Special edition paper

Overhead Contact Line Monitoring and Prediction of Contact Wire Localized Wear Points



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JR East is developing an overhead contact line condition monitoring system to be equipped to trains in operation so as to obtain frequent data about contact wires. In order to extend the period between replacement of contact wires, it is necessary to develop methods for predicting localized wear of the wire. We are thus analyzing measurement data of contact wires from obtained by an inspection train by applying “data analytics technology”.

●Keywords: Train in operation, Contact wire, Wear, Monitoring, Condition-based maintenance

1 Introduction

JR East conducts measurement of overhead contact line equipment using an electric and track inspection car called “East-i” to manage that equipment on all Shinkansen and conventional lines (Fig. 1). The items to be measured include contact wire wear (residual diameter of wire), deviation, height, obstacles, hard spots, impact by pantographs, interval distance, and length of parallel zone. On conventional lines, the East-i runs four times a year to continuously record the condition of the overhead contact lines. The data is utilized for the maintenance of overhead contact line equipment.

Fig. 1 Electric and Track Inspection Car for Conventional Lines (East-i)

It is empirically known that local wear of contact wires where wearing rapidly progresses is caused by factors such as separation of pantographs and sliding of auxiliary contact strips of pantographs due to excessive deviation, as seen in Fig. 2.[1] At the points of local wear found by the inspection car system that processes the measurement data by the East-i, however, that system simply judges whether or not the measured values exceed the threshold for the residual diameter of wires. It cannot detect overhead contact line system failures (height, deviation, etc.) that lead to local wear, information that could be used to prevent local wear or reduce the amount of wearing.

Contact wires are equipment where serious operation disruption would occur if severed. They thus have to be replaced before reaching their wear limit, and that work involves large

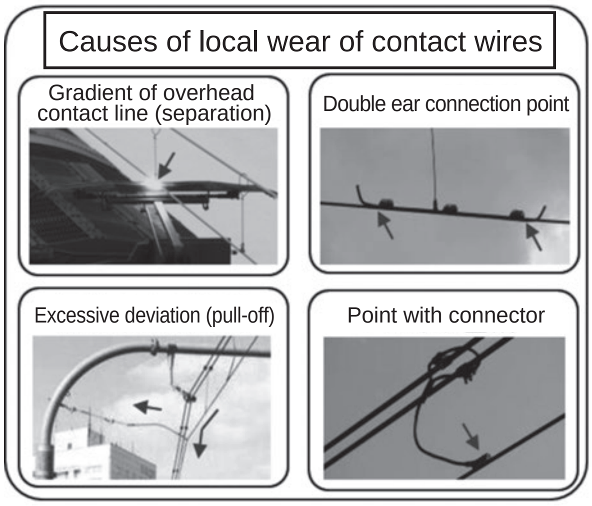

Fig. 2 Empirically Known Causes of Local Wear of Contact Wires

costs. Even when being replaced due to local wearing, contact lines need to be replaced in lengths of a few to tens of meters to connect them to each other. Furthermore, at the connection point, contact lines wear rapidly due to their own weight.

For both risk management and cost reduction reasons, a new equipment management approach is needed where the factors causing local wear are analyzed based on measurement data of the contact wires as shown in Fig. 3 to prevent local wear.

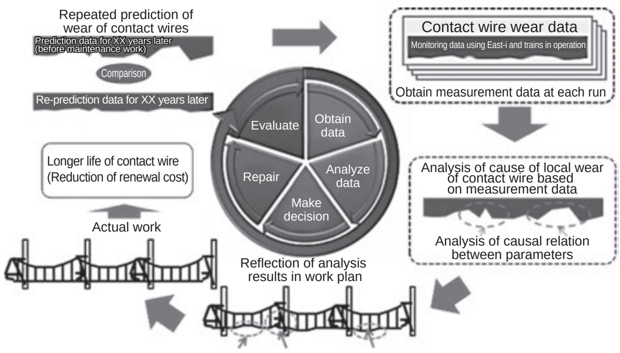

Fig. 3 Measures to Prevent Local Wear of Contact Wires

In light of this situation, the Technical Center is developing an overhead contact line condition monitoring system that can be equipped to trains in operation to allow frequent monitoring of contact wires. We are also studying methods to predict points where contact lines wear and the amount of wear, based on

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the correlation between and tendency of the amount of wear and other parameters such as height and deviation of contact wires. Such correlation and tendency will be analyzed from past overhead contact line system measurement data from East-i by data analysis methods that have made great technical advances in recent years.

In this paper, we will introduce our efforts on monitoring contact wires and prediction of local wear. We will further explain the results of studies on deepening condition-based maintenance (CBM), which focuses on keeping occurrence of local wear of contact wires under control.

2 Monitoring of Contact Wires

2.1 Prototype Overhead Contact Line Condition Monitoring System (for MUE-Train)

From fiscal 2008 to 2013, we conducted running tests to check functions and collect data for a prototype overhead contact line condition monitoring system having a contact wire monitoring function[2]. That system was installed on the MUE-Train, a multi-purpose test train of JR East.

The prototype consisted of a rooftop unit on top of and an onboard controller inside car No. 6 (with motors). The configuration is shown in Fig. 4, and the system has the functions listed in Table 1. Initially, the prototype had only functions for real-time detection of impact of the pantograph and pantograph separation due to abnormalities in the border area between the overhead contact line equipment including contact wires and pantographs. It would issue an alarm to the dispatcher's office and maintenance-related departments if those incidents occurred.

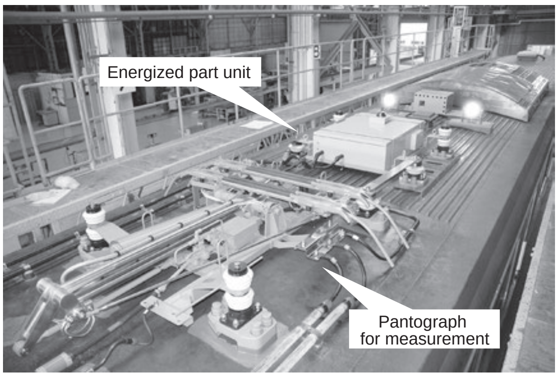

Fig. 4 Rooftop Unit of Overhead Contact Line Condition Monitoring System (for MUE-Train)

Table 1 Functions of Prototype Overhead Contact Line Condition Monitoring System

Sensor	Detected item
Pantograph accelerometer	Detects imact of pantograph with metal fittings and obstructions
Optical separation sensor	Detects arcs generated when pantograph separates from contact wire
Pantograph monitoring camera	Checks status of pantograph contact with contact wire

2.2 Overhead Contact Line Condition Monitoring System for Trains in Operation (Installed on Series E235 Pre-production Cars)

2.2.1 Overview and Functions of the Model

Based on the results of tests using the prototype installed on the MUE-Train, we developed an overhead contact line condition monitoring system that can be installed on trains in operation. Components are concentrated in a rooftop unit and in an underfloor unit cabinet, and the system consists of a control unit installed under the floor and rooftop devices. The control unit is linked with the rooftop devices and the train control system (INTEROS) as shown in Fig. 5. The system automatically obtains information on time and location (line name, line type, kilometerage), running speed, train number, and the like to be added to the monitoring data with an aim of simplifying the onboard devices and achieving unmanned operation.

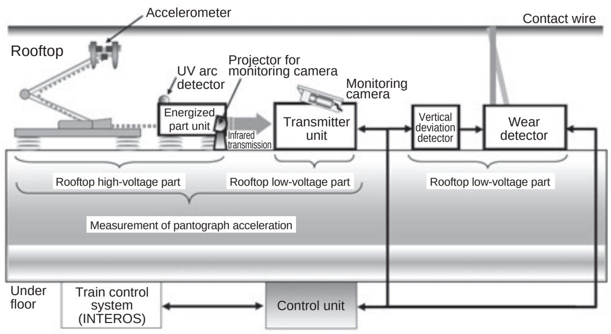

Fig. 5 System Configuration of Overhead Contact Line Condition Monitoring System for Trains in Operation

The model has a function where it collects overhead contact line measurement data as obtained by the East-i and records that with the onboard equipment and wayside system. This is in addition to an abnormality detection and warning function studied using the prototype. To the items measured, we added height, deviation, and wear (residual diameter) of contact wires, which are important to judge the condition of contact wires (Table 2).

Table 2 Functions of Overhead Contact Line Condition Monitoring System for Trains in Operation

Sensor	Detected item
Pantograph accelerometer	Detects impact of pantograph with metal fittings and obstructions
Optical separation sensor	Detects arcs generated when pantograph separates from contact wire
Pantograph monitoring camera	Checks status of pantograph contact with contact wire
Contact wire height and deviation detector (Rotary laser device)	Measures height and deviation of contact wire
Contact wire wear detector (infrared LED device)	Measures contact wire wear (residual diameter) and detects electric poles

Trains in operation are equipped with the system having those functions, and those are repeatedly run and frequently collect data about the same measurement items as are measured by the East-i. We expect that will allow us to identify in detail changes in the condition of contact wires we previously could not identify. Consequently, it should allow us analyze factors such as local wearing of contact wires, which could lead to deterioration of the overhead contact line system.

In particularly, series E235 pre-production cars equipped with the system are run on the Yamanote Line, where we expect them to run on the same section up to 17 times a day. We expect to be able to obtain data hundreds of times more frequently that with measurement by the East-i, which is the optimum frequency for verifying the effects of more frequent data acquisition.

2.2.2 Contact Wire Height and Deviation Detector

East-i measures the height of contact wires (above the track surface) using a potentiometer linked to vertical movement of the measurement pantograph and the deviation of contact wires (lateral position seen from the center of the track) using a laser device installed in the car. Considering maintainability of the cars and the size of the devices, however, it is difficult to install such devices in trains in operation.

Thus, in order to make the model for trains in operation not be an obstacle in the cabin and to allow it to be install onto the train rooftop and within the rolling stock clearance, we adopted a smaller laser positioning device to measure the height and deviation of contact wires (Fig. 6). With four synchronized laser positioning devices placed in parallel, the model can have intervals a quarter those of one device, being more compact-sized.

The East-i is equipped with a mechanism where laser beams are not emitted when the train is running at less than 5 km/h. This is a measure to protect people around the train when it is entering/exiting stations and while stopped at a station because the intensity of laser beam of the laser device of the East-i falls under class 3B of JIS C 6802 (Safety of laser products). On the other hand, the model for trains in operation needs no mechanism for bodily protection by laser beam emission control and the like because the intensity of laser beam of the model is small, categorized as class 1.

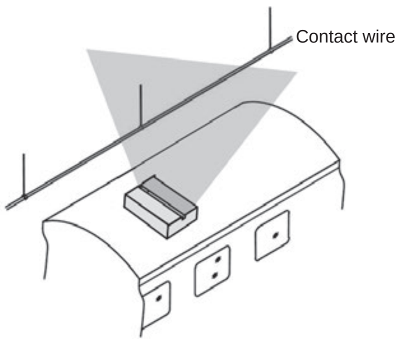

Fig. 6 Contact Wire Height and Deviation Detector

2.2.3 Contact Wire Wear Detector

The device adopted for East-i to measure wear of contact wires (residual diameter of wire) is the same laser device used for measuring height and deviation as explained in 2.2.2.

The device uses high-intensity infrared LEDs as the light source for measurement, needing no measures for bodily protection by a laser beam emission control mechanism and the like as with the contact wire height and deviation detector (Fig. 7).

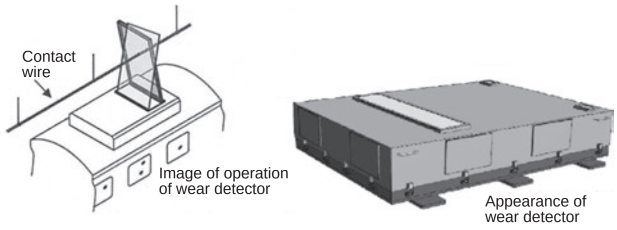

Fig. 7 Contact Wire Wear Detector

3 Prediction of the Amount of Local Wear of Contact Wires

3.1 Analysis Data

In analysis of data of East-i, we expect to be able to find unknown correlation and regularity from a large amount of data by applying the latest data analysis technologies. This is found in addition to proving the mechanism of generation of local wear of contact wire as an empirical assumption based on analysis results.

We thus tried to extract local-wear-generating factors that should be monitored. In this effort, we set data output by the East-i system and secondary generated data as the explanatory variables and set data of points where local wear of contact

Table 3 List Data Analyzed (selected)

Explanatory variable	Details, example
Line name	Line name (XX Line, etc.)
Line type	Line type (inbound, outbound, single line, etc.)
Structure of overhead contact line	Simple catenary, compound catenary, integrated catenary, etc.
Type of contact wire	GT-Sn110º, GT-M-Sn170º, etc.
Height	Height of contact wire (above track surface)
Average height	Average height of latest three measurements
Maximum height	Maximum height of latest three measurements
Height variance	Height variance of latest three measurements
Wear	Residual diameter contact wire
Wear difference	Wear differences before each of latest three measurements and current measurement
Dynamic deviation	Deviation of contact wire (seen from center of track)
Gradient	Gradient of contact wire (span)
Hard spot	Vertical impact acceleration of pantograph
Pantograph impact	Impact acceleration of pantograph in track longitudinal direction
Train speed	Train running speed
Air section	Air section location (span)
Air joint	Air joint location (span)
Discontinuous electric pole number section	Location with structure such as bridge and station

wires to be analyzed occurred (extracted from the list of points requiring attention) as the objective variable. The items among the explanatory variables shown in Table 3 that are strongly correlated with the objective variables can be seen as the factors that generate local wear.

3.2 Problems in Data Analysis and Future Efforts

When observing the difference between the data of individual measurement sections in intervals of three months, we found cases where the residual diameter of the contact wire increased over time instead of decreasing (wearing) (Fig. 8) and other cases with noise and other offset generated by uniform error in overall measurement data (Fig. 9). Furthermore, the results of the aforementioned data analysis greatly differed from the prediction results.[3)]

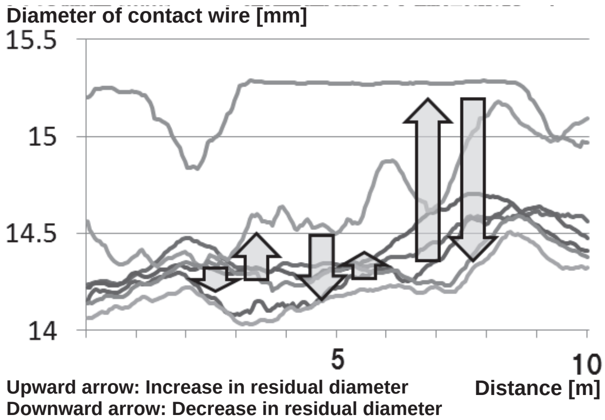

Fig. 8 Change of Measurement Values of Diameter of Contact Wire Residual Diameter for Seven Measurements in Series

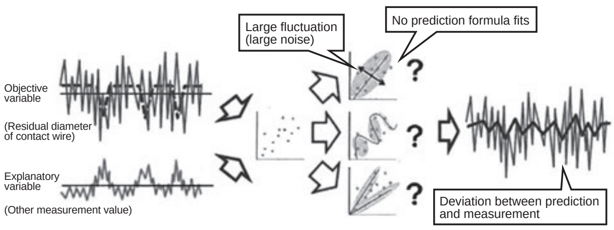

Fig. 9 Effect of Noise on Prediction Results

The probable causes of such phenomena are as follows.

(1) Measurement error of the laser positioning device (irregular reflection noise of laser beam due to rough surface of contact wire damaged by pantograph contact strips, etc.)

(2) Incorrect measurement position (positioning error due to mis-detection of electric poles, difference of wheel diameter used in counting of kilometerage, etc.)

The overhead contact line condition monitoring system to be installed on trains in operation measures based on the same principles as with the East-i. It also uses position information obtained by optically detecting electric poles and kilometerage information from INTEROS calculated by wheel diameter. The same problems can thus occur in analysis of the data frequently obtained using trains in operation. For that reason, we have to make improvements such as noise filtering and automatic adjustment of measured waveform using the maximum deviation of contact wires at the electric pole support points. We will thus continue to consider specific methods for implementing those improvments.[4)] Into the future, we will examine the possibility of solving those problems and systematically predicting points where local wear of contact wires can occur and the amount of wear.

4 Conclusion

JR East has been managing wear of contact wires mainly based on measurement data obtained by the East-i. This is a rare example in railway electric facilities were CBM is applied. In order to further improve the safety and economic efficiency of facilities while dealing with conditions such as a future decrease in maintenance engineers and the need for cost reduction, however, it will be necessary to deepen CBM and drastically innovate the style of maintenance work for electric facilities. This will be done by accumulating a large volume of data using ICT monitoring devices introduced in this paper and accurately detecting and predicting the deterioration level of the facilities based on data analysis.

The Technical Center calls such innovation the “Smart Maintenance Initiative”. For contact lines, the center aims for a system change to a maintenance method where measures can be taken to prevent wear of contact wires before they actually wear. That will be done by predicting local wear of contact wires by combining frequent data collection using the monitoring system explained in this paper with data analysis technologies. We still have many issues to overcome in terms of prediction of contact wire wear in particular; however, we will continue efforts to solve them one by one so as to achieve the Smart Maintenance Initiative.

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