Development for New Functions of OCS Inspection System

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Abstract

Since the development of the first model, the Overhead Catenary System (OCS) inspection system, CATENARY EYE, has continuously reinforced its functions. Such changes are primarily based on the fact that electric railway facilities are composed of various facilities, and that new facilities have been developing and introduced to the customers. On this account, our OCS inspection system has been required to meet to such conditions. For the most updated functions, we have newly developed its technologies, such as "static wire position measurement method: measurement of clearance of separation between the main line and crossing wire" and "automatic compensation for measuring position by elastic-matching method." The former is a function with the use of an accurate measuring approach to define a static wire position so that the separation in stagger and height between the main line and crossing wire can be precisely measured and that encroaching position with a pantograph is accurately observed by using cameras. The latter is a function to accomplish an automatic measuring-position compensation during a contact wire inspection that previously had to be performed manually in the past. Since such a position correction work is automated, work efficiency has been greatly improved.

1 Preface

Since the first model of our contact wire inspection system was delivered to JR Kyushu Railway Company in 2003, we have shipped the systems to many other railway companies. So far, we have improved and added many measurement functions such as wear of contact wires, contact force, contact loss detection. Overall quality level has also been improved. It includes the extension of operational life for devices, updating of hardware renewal to improve accuracy, and accuracy improvement for already developed and existing measuring functions.

This paper introduces newly developed technologies such as the "function of static wire position measurement method: measurement of clearance of separation between the main line and crossing wire" and "automatic compensation for measuring position by elastic-matching method." Each function will be put into practical use during fiscal year 2015.

2 Static Wire Position Measurement Method: Measurement of Clearance of Separation between the Main Line and Crossing Wire

2.1 Purpose

This function is used for contact wire inspection on crossing wires (see Fig. 1) whose overhead wire structure is complex in railway facilities. The separation between the main line and crossing wire is measured. In so doing, it measures the safety level

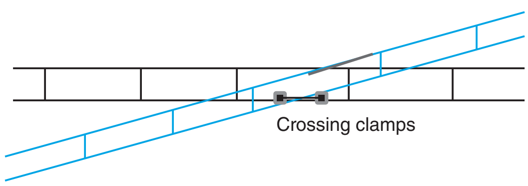

Fig. 1 Outlined Diagram of Crossing Wires Section

In a crossing section of crossing wires in a trolley line, the possibility of contact loss is considered high. For this reason, crossing clamps are used to lower the height of the crossing wire side in order to reduce the contact loss. At the crossing section, the trolley of the main-line is set at a lower level than crossing wire.

at the time of the contact between the pantograph and contact wire while a train is traveling (passing by).

2.2 Measuring Method

(1) Non-contact measurement

Two LS cameras are used for the simultaneous measurement of height and stagger of the main line and crossing wires in non-contact manner.

(2) Principle of measurement

The two LS cameras make it possible to perform high-accuracy measurement at the Shinkansen's commercial service speed. With these cameras, stereo image measurement is carried out. The LS cameras intended for the measurement of stagger in the main line are simultaneously used for measurement in the same position. As a result, it can accurately measure the measurement of clearance of separation between the main line and crossing wire height at a position of 900mm from the track center. **Fig. 2** shows testing equipment for static wire position measurement.

For the measurement of a position of contact with a pantograph, the first contact position is defined based on the locus of pantograph height and another locus of height and stagger observed when the crossing wire is encroaching on the pantograph. This function is outlined in **Fig. 3**.

(3) Measurement at the commercial service speed

Measurements are possible at the commercial service speed. It can cover the commercial service speed of conventional train lines or Shinkansen.

(4) Basic measuring items

(a) Crossing wire height and stagger

(b) Point of pantograph encroachment

(5) Permissive accuracy

Crossing wire height and stagger within 3mm

Measuring accuracy can change according to the setting conditions of applicable vehicles and band of catenary height fluctuation. In order to satisfy coordination with these conditions, camera lenses are adequately selected and conditions of setup are carefully examined.

2.3 Measurement Test

For the crossing wire measurement test, we adopted two LS cameras as shown in **Fig. 2** and the laser apparatus for the examination of the result of measurement.

(1) Structure of contact wire for examination

We prepared overhead wires for testing. They have a difference in height of no more than 30mm and no less than 30mm between the main line and crossing wires.

(2) Method of examination

The measuring position was checked for the main line and crossing wires in advance. Height and stagger were manually measured to obtain true values. After this measurement, testing measurement started with testing systems carried on a vehicle. To verify the measurement errors, the measured values were compared with the true values. Before measurement, two LS cameras were used to make calibration by stereo image measurement. By this approach, basic accuracy was confirmed to attain the following results:

(a) Mean error in stagger: 0.428mm

(b) Mean error in height: 0.842mm

(c) Mean error in distance: 0.995mm

Fig. 2 Examination Equipment for Static Wire Position Measurement

Stereo image measurement is carried out with the LS cameras positioned on the right and left in order to detect the wire position. As seen in this picture center, a range scanning laser (a distance measuring device) had been used as a supporting device for verification.

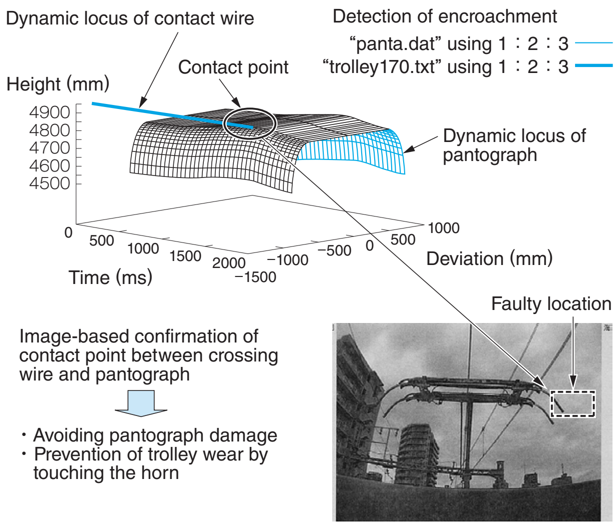

Fig. 3 Static Wire Position Measurement and Detection of Crossing Wire Encroachment

A method is shown to calculate the contact point between a pantograph and a crossing wire (trolley) by stereo image processing.

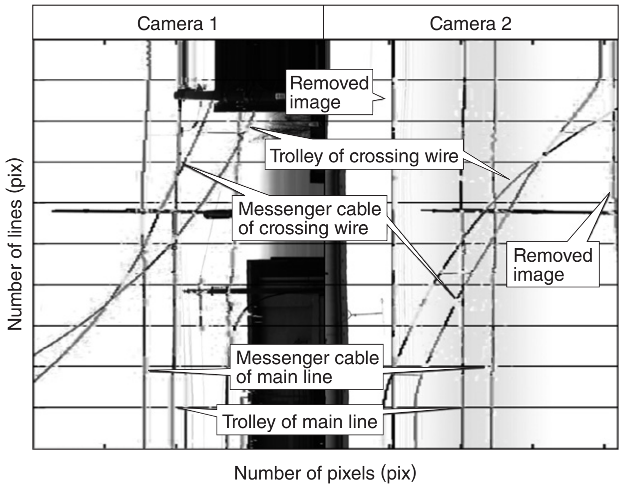

Fig. 4 Result of Static Wire Position Measurement

This is an image of a crossing wire position measurement. It includes irrelevant images of facilities other than the main line and crossing wire. These irrelevant images are considered noise and removed.

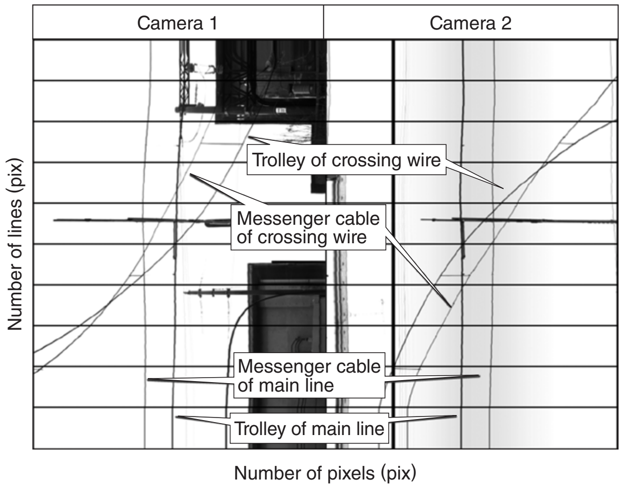

Fig. 5 Original Image of Crossing Wire for Static Wire Position Measurement

This is an original image of a crossing wire for static wire position measurement. It includes images of facilities other than the main line and crossing wire. These images are removed.

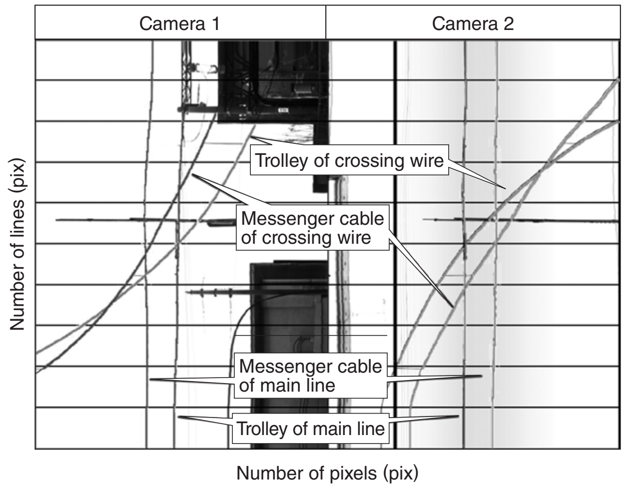

Fig. 6 Result of Crossing Wire Measurement for Static Wire Position Measurement

The result of obtaining the center coordinates is shown, determined from the segments of the main line and crossing wire based on the original image of a crossing wire for a static wire position measurement. According to the obtained coordinates, height and stagger are recorded.

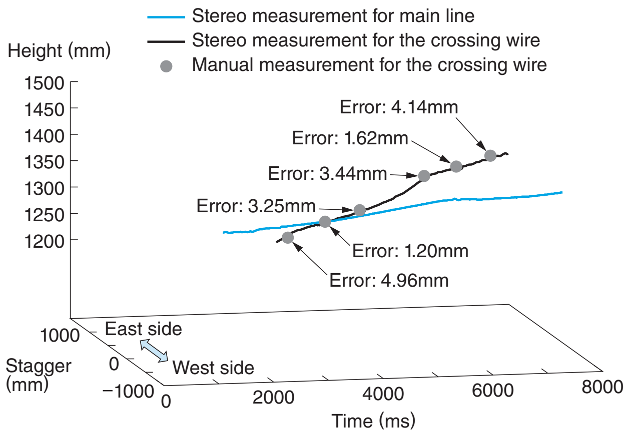

Fig. 7 Result of Crossing Wire Measurement for Static Wire Position Measurement

The result of the measurement shown in Fig. 5 is plotted in stereo mode. Error values at six points indicate the comparison with values obtained from manual measurement.

The above results were obtained under the conditions that the measuring system remained still and calibration tools were used. The static accuracy obtained through stereo measurement was found to be less than 1mm.

(3) Result of measurement

Fig. 4 shows the result of static wire position measurement. Images of crossing wires are shown, measured by two LS cameras. These cameras installed on the right and left show images of the main line and crossing wires.

Fig. 5 shows an original image of crossing wire for static wire position measurement. Fig. 6 shows the result of crossing wire measurement for static wire position measurement. Based on the result of stereo image measurement on the original image, the figure shows the wires where the center positions of the main line and crossing wires were obtained. Based on the coordinates of these center positions, height and stagger of the main line and crossing wires can be determined. Fig. 7 shows this result expressed in 3D coordinates. Where error values were plotted, positions by manual measurement were indicated. Table 1 shows the result of the

Table 1 Result of Crossing Wire Measurement for Static Wire Position Measurement

This table shows a difference in main line and crossing wire measurement between actual and manual measurement.

		West side			East side		
		Stagger 926mm	Stagger 638mm	Stagger 351mm	Stagger 245mm	Stagger 531mm	Stagger 825mm
The difference between high and low (mm) (crossing wire and main line)	Manual measurement	37	38	33	36	35	36
	Stereo measurement	41.96	39.20	29.75	32.56	33.38	31.86
Error between actual and manual measurement (mm)		−4.96	−1.20	3.25	3.44	1.62	4.14

Error on average: 3.10mm

comparison of manually measured values and stereo-measured values. The result for this case indicates that the mean error is 3.10mm. It should be noted that the test in this case showed an unusual measurement result because the catenary structuring is substantially irregular with the separation on the height set at more than 30mm. The measurement errors therefore tended to be large where such stagger values were set high.

(4) Conclusion and future challenges

(a) Result of calibration

A static accuracy of 1mm or less can be attained with two LS cameras. As described above, however, applicable lenses may be changed by the conditions of the contact wire height and stagger as well as rooftop conditions of the vehicle with the inspection system. For this reason, it is essential to obtain static accuracy by calculation before application.

(b) Result of measuring accuracy

Errors tend to be large where stagger is high. As a solution, a compensation for characteristics of camera lenses should be performed at the time of calibration. It is known that errors can be suppressed into an average range if the said treatment has been performed. Where crossing clamps are used for the main line and crossing wires, a clamp is superposed on the main line and a contact wire appears wide as a result; this further results in an increase in errors. As a solution, a countermeasure should be taken with the use of an image of sliding surface (wear) on the main line located on the lower side.

The measuring speed had been set at a lower rate in order to avoid adverse influence caused possibly by sway motions of the vehicle. If measurements are intended in a commercial operation vehicle, it is necessary to take adequate measures against high speed running and compensation processing for a contact wire stagger using the measured swaying angle of the vehicle. For measures to be taken against high speed vehicle operation, the sampling frequency of the LS camera may be changed according to the vehicle speed. It is then possible to conduct measurements at speeds up to 300km/h. Compensation for the vehicle swaying is already possible by virtue of existing technologies. More accurate measurement is possible by the adequate compensation function synchronized with images of the LS camera.

3 Automatic Compensation for Measuring Position by Elastic-Matching Method

3.1 Purpose

In a former contact wire inspection system, the measuring point was defined based on wheel encoder signals and kilometrage data of the ATC signal. There was, however, a significant issue that the measured point falls out of position due to its errors.

For this reason, it took a laborious amount of time to make a span length correction at the time of comparison with past data of each measurement or statistical treatment for each span length. The newly developed function, elastic-matching method based compensation, provides a new approach to make automatic compensation for the span length. This technology is intended to substantially reduce span length compensation work.

3.2 Elastic-Matching Method

In consideration of expansion and contraction of data position due to variations in vehicle speed, we employ a correction method called “elastic-matching method.” As a preliminary arrangement for data matching for each measurement, the basic data are set up so that the data obtained from each measurement can be compared with the basic data. The result of this data matching can be used for automatic span length compensation.

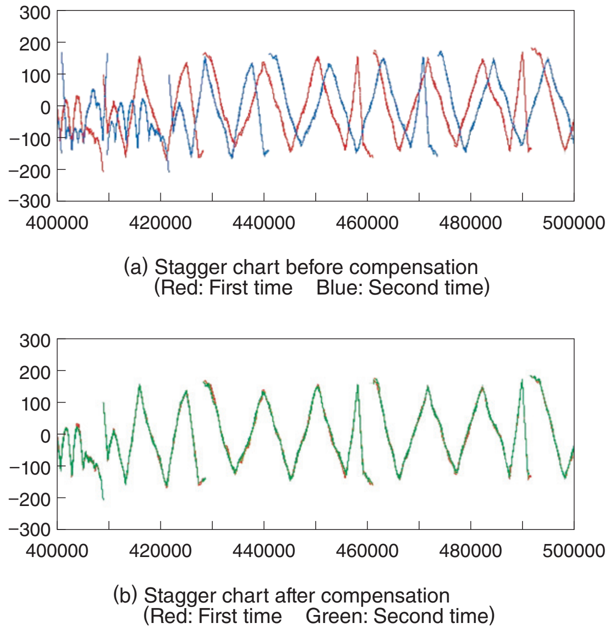

Fig. 8 **Automatic Compensation for Measured Positions: Stagger Example 1**

The upper chart (a) shows staggers measured twice. There is a difference in position between both. The lower chart (b) shows the result of automatic compensation. It shows almost identical positions measured by measurements taken twice.

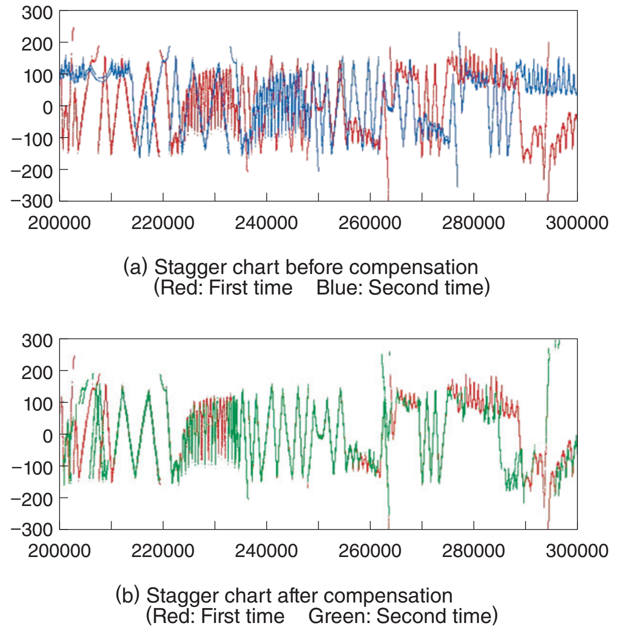

Fig. 9 **Automatic Compensation for Measured Positions: Stagger Example 2**

The upper chart (a) shows staggers measured twice. There is a difference in position between both. The lower chart (b) shows the result of automatic compensation. It shows the almost identical positions by measurements taken twice; but due to a difference in measured values, there are some areas showing no identical data.

3.3 Result of Examination

Examination by this approach is carried out with the use of actual data obtained from the OCS inspection. Figs. 8 and 9 show the result of automatic span length compensation performed by this approach and is based on the result of the stagger analysis done twice. The red and blue lines at (a) correspond to the chart of stagger analysis repeated twice. The chart at (b) shows the result of automatic compensation where this approach had been applied.

Figs. 10 and 11 show the result of wear analysis repeated twice. In the measurement of wear and stagger, the sampling frequency is dynamically changed according to the vehicle speed. In addition, the measuring pitch is set very short, generally at a few centimeters. The measuring position is, therefore, always elastic and it is very difficult to overlap mutual positions. From the obtained results, we concluded that the automatic position compensation function by using the proposed method is quite effective because mutual positions are almost identical. This approach is effective for statistical treatment in the unit of span length and an accurate data output of distance from a pole to a faulty spot can be made.

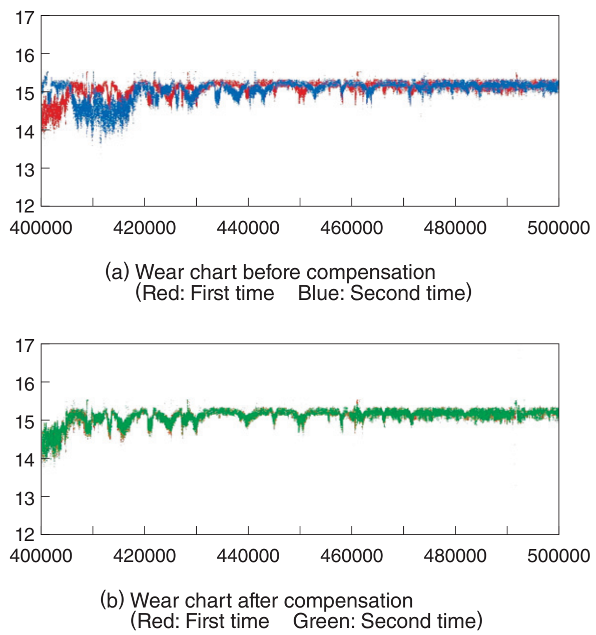

Fig. 10 **Automatic Compensation for Measured Positions: Wear Example 1**

The upper chart (a) shows wear measured twice. There is a difference in position between both. The lower chart (b) shows the result of automatic compensation. There are almost identical positions by measurements taken twice.

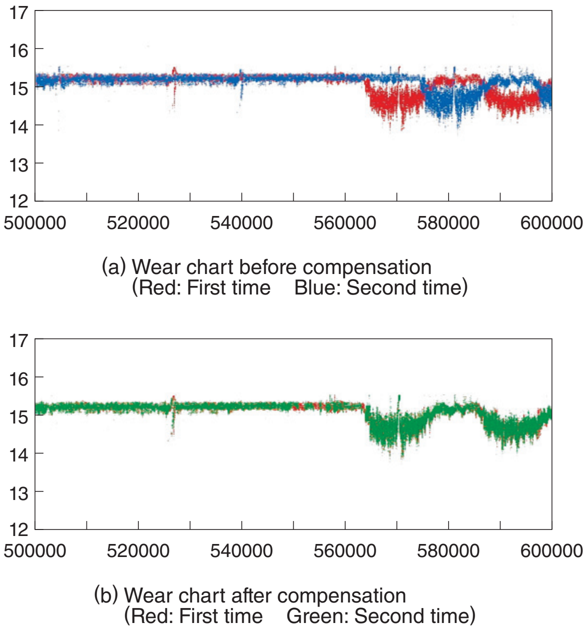

Fig. 11 **Automatic Compensation for Measured Positions: Wear Example 2**

The upper chart (a) shows wear measured twice. There is difference in position between both. The lower chart (b) shows the result of automatic compensation. It shows almost identical positions by measurements taken twice.

4 Postscript

This paper introduced the newly developed functions of the OCS inspection system, CATENARY EYE. Since automatic measurement of separation in crossing wires was difficult to achieve by the conventional method, manual measurement was performed at night. Our new system makes it possible to perform the same measurement together with other measuring items simultaneously. It is possible to reduce night work with this method. In regard to the auto-position compensation function, data about distance from pole to faulty location and also various control data such as minimum values, maximum values, and deviation for each span length have to be collected into a measurement report. Formerly, amounts of labor hours had been consumed for such compensation work with the collected data. Currently, such labor hours, however, can be reduced. For people in charge of the inspection and maintenance of catenary system, release of our new system will substantially reduce their work load burden. Both functions introduced in this paper will be released for the actual system during fiscal year 2015.