Crossing Wire Measurement System for High Speed Rail

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Abstract

Under Overhead Line Equipment (OLE), trains run at a high speed like the Shinkansen. Contact wire wear is caused by a construction stage alignment error or an alignment change over time between the height of the main line and the crossing contact wire. This wear gives rise to a negative impact on the OLE. When crossing wires are built over cross-overs points or such wires face inspection and maintenance work, it is necessary to check and manage the conformity to the relevant standard on the height of the main lines and crossing wires.

Our newly developed crossing wire inspection system for high speed railways is loaded on a maintenance vehicle. It can precisely and automatically measure the height, stagger, and wear of the main line and crossing wires. In addition, the result of measurement data obtained on the spot can be sent out to check if the crossing wire conforms to the relevant standard on the catenary system.

1 Preface

A cross-over track line is a track for connecting two parallel rail tracks (up line or down line). Over the cross-over track line points, it is common for the trolley contact wires to intersect (firmly fixed by the metal fixture). In this paper, the overhead catenary line (trolley contact wire) over the cross-over track line is called a “crossing wire”.

The overhead lines (trolley contact wire) over two parallel rail tracks (up line and down line) are called the “main lines” (this is not a track but the trolley contact wire). In the overhead area of the cross-overs points, the height of the main line and the crossing wire is generally kept constant. This is to allow the pantograph to draw power safely. In this paper, this crossed catenary area is called “Cross-overs Points.” Currently, at the Cross-over Points of the Shinkansen Lines, there is a gradual transformation from the conventional crossing catenary structure to a non-crossing catenary structure (parallel or over the top of the other catenary). The reason for such change is that in the case of a conventional crossing catenary system a metallic hardware affixed to the crossing points of two contact wires becomes a hard spot and this may lead to a rapid wear of the contact strip of the pantograph and of the contact wire.

When the travelling pantograph makes direct contact with the main line and the pantograph passes through just under the crossing wire, if the height of the crossing wire is lowered for any reason, the pantograph will make contact with the crossing wire which will lead to issues regarding wear.

For this reason, the non-crossing catenary system (parallel or over the top arrangement to other contact wire in the Cross-over Points) has been introduced because this system does not use any fixture at the crossing points. There is also no possibility that the travelling pantograph, which makes direct contact with the main line, will make contact with the crossing wire.

This paper introduces the features, performance, and the result of measurements in regard to our “crossing wire inspection system for high speed railways” developed for the accurate measurement of crossing wire height, stagger, and wear.

2 Features of the Inspection Equipment

(1) Non-contact measurement of the crossing wire

Height and stagger of the main line and crossing wires are measured by a laser range scanner in a non-contact mode. We realized high measuring accuracy (within ±5mm) by identification processing for contact wires and suspension wires and a filtering treatment. Since a measuring function for wear (by using a line sensor) is available, it can grasp the result of measured height and stagger at each crossing point together with the state of wear progress.

(2) Removability

Since the inspection equipment can be carried, installation and removal of equipment can be easily accomplished in the dedicated maintenance train vehicle.

(3) On-board analysis

When an analytical processing function is included in a desktop PC installed in the maintenance train vehicle, the results of measurement can be checked on-board the train.

(4) Operability

A desktop PC for data processing and a laptop PC for system operation are located separately and are connected wirelessly. Even in the case of a maintenance train vehicle with limited driver's operating desk space, the inspection equipment operation is possible by using the laptop PC on the desk and putting away the desktop PC.

3 Applicable Conditions

This equipment is applicable under the conditions specified below.

(1) Measuring conditions

(a) Nighttime measurement

(b) Measuring speed: Max. 20km/h

(2) Measuring items and accuracy

Table 1 shows the items and accuracy of measurements with this equipment.

(3) Measuring method

In the stagger position set on the basis of a main line (or a crossing wire) defined for each crossing wire structure, the height of the main line and crossing wire is measured and the vertical distance between the two contact wires is calculated. The method of measurement for each crossing wire structure is described below.

(a) Crossing wire (for low speed) (see **Fig. 1**)

(i) Stagger of a contact wire ±900mm (Based on the center of a main-line track)

(b) Crossing wire (for high speed) (see **Fig. 2**)

(i) Stagger of a contact wire ±300mm, ±600mm, and ±900mm (Based on the center of a main line-corresponding track)

Table 1 Items and Accuracy of Measurements

Items and accuracy of measurements are shown.

Measurement item	Applicable sensor	Output	Static inspection accuracy
Contact wire height	Laser	Height of main line and crossing wire (mm) CH number: 4	±5mm Range of contact wire height: 4800 ~5300mm
Stagger of contact wire	Laser (LS camera)	Stagger of contact wire and crossing wire (mm) CH number: 4	±5mm Range of contact wire stagger: the main line ±300mm (with OV) Crossing wire ±1100mm
Wear in contact wire	LS camera	Residual diameter of the main line (mm) CH number: 4	0.1mm basis Sampling period: pitch of 3cm or less at 20km/h Stagger width: measurable within ±300mm
Positional information	Doppler sensor	Car position	±0.2%
	Support bracket detection sensor	Steady brace and pull-off arm position (Distance in kilometers)	Response time: 500μs or less

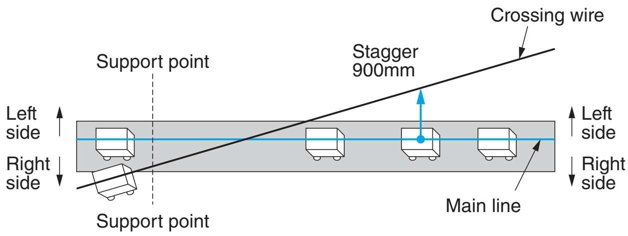

Fig. 1 Measuring Method for Crossing Wire (for Low Speed)

Running along the main line, measurements are carried out for the main line and crossing wires. The vertical distance between the main line and crossing wire is measured in the position where the stagger value of the crossing wire is ±900mm from the center of the main line-corresponding track.

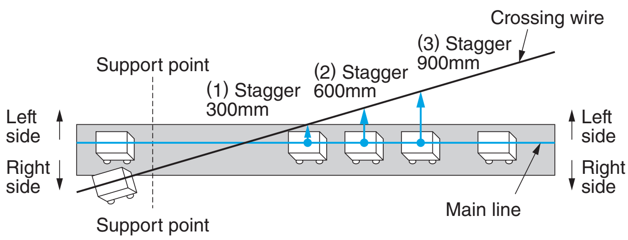

Fig. 2 Measuring Method for Crossing Wire (for High Speed)

Running along the main line, measurements are carried out for the main lines and crossing wires. The vertical distance between the main line and the crossing wire is measured in the position where the stagger value of the crossing wire is ±300mm, ±600mm, and ±900mm respectively from the center of the main line- corresponding track.

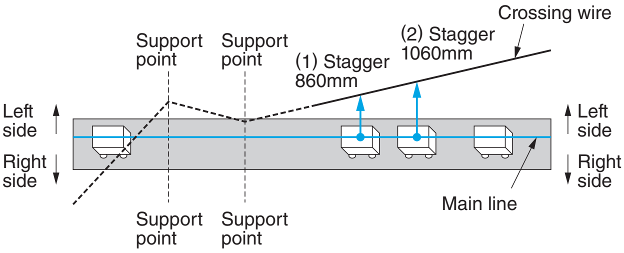

Fig. 3 **Measuring Method for Non-Crossing System (Based on Main Lines)**

Running along the main line, measurements are carried out for the contact wire for the main line and crossing wires. The vertical distance between main line and crossing wire is measured in the position where the stagger value of the crossing wire is ±860mm and ±1060mm respectively from the center of the main line-corresponding track.

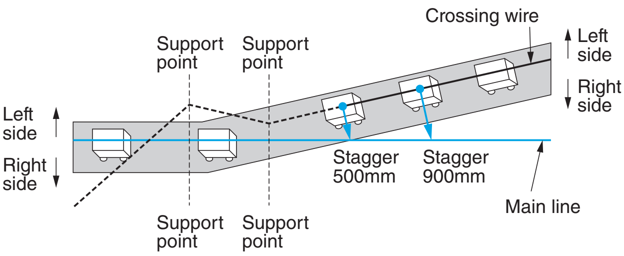

Fig. 4 **Measurement for Non-Crossing Catenary (Based on a Crossing Wire)**

Running along a crossing wire, measurements are carried out for the main lines and crossing wires. The vertical distance between main line and crossing wire is measured in the position where the stagger value of the contact wire for the main line is ±500mm and ±900mm respectively from the center of the crossing wire-corresponding track.

(c) Non-crossing wire

(i) Stagger of a contact wire ±860mm and ±1060mm (Based on the center of a main line-corresponding track) (see **Fig. 3**)

(ii) Stagger of a contact wire for a main line ±500mm and ±900mm (Based on the center of crossing wire-corresponding track) (see **Fig. 4**)

4 Inspection Equipment Configuration

Fig. 5 shows the inspection equipment configuration.

4.1 Rooftop Equipment

Rooftop Equipment is composed of a laser range scanner for measuring the height and stagger, a camera box and lighting for measuring the amount of wear, and a support bracket detection sensor for detecting a pull-off arm position. Each

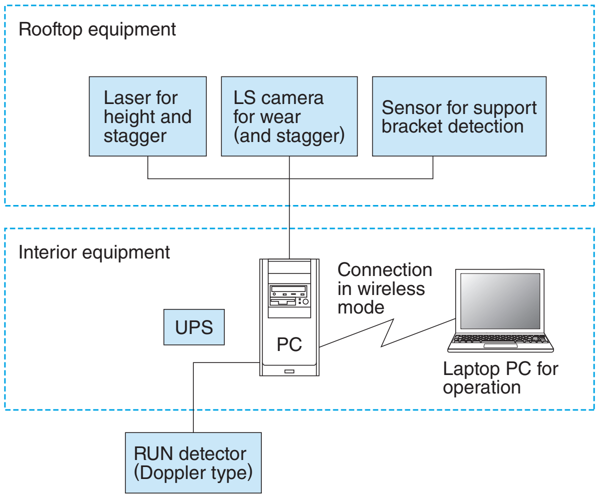

Fig. 5 **Inspection Equipment Configuration**

Various sensors are arranged in the rooftop equipment and data from these sensors are processed and saved in the interior equipment.

Fig. 6 **Rooftop Equipment**

This equipment is composed of a laser range scanner used to acquire data about stagger in height, a camera box and its lighting device to measure wear, a pull-off arm, and a support bracket detection sensor to detect a clamping action. These devices are in modular design so that each device can be carried by hand.

measuring device is mounted on a separated type pedestal that is firmly affixed on the rooftop of a dedicated maintenance train vehicle. **Fig. 6** shows the rooftop equipment.

4.2 Interior Equipment

Interior equipment is composed mainly of a desktop PC for data processing, power source for lighting, an Uninterruptible Power System (UPS), and a laptop PC for operation. The PC and related peripheral equipment are contained in a portable

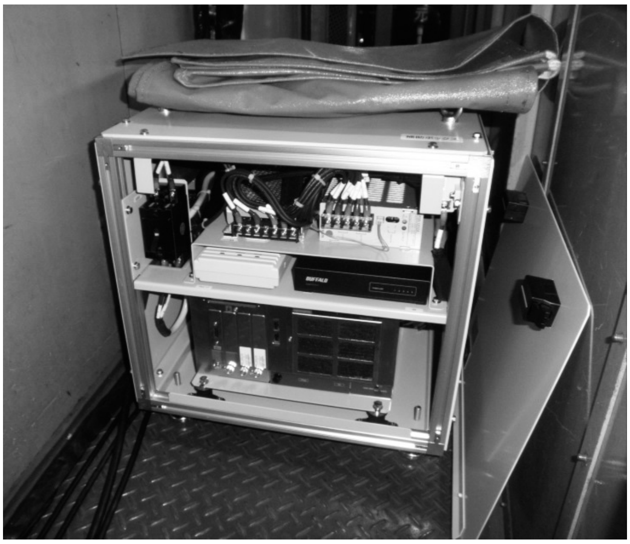

Fig. 7 Interior Equipment

The desktop PC for data processing and saving and the DC power supply for other equipment are accommodated in a portable box.

box type enclosure. Lighting equipment and UPS are installed on a compact rack. Thanks to such space-saving arrangement, all necessary equipment can be accommodated in a narrow space in the maintenance train vehicle. Fig. 7 shows the interior equipment.

5 Measurement Result Display

The result of measurements analyzed by this equipment is compiled in a form of inspection reports or spreadsheet file format. It is later expressed in a chart (table or graph). Fig. 8 shows a screen display of the measurement result in an inspection report format, Fig. 9 shows a screen display of the measurement result in a spreadsheet format, and Fig. 10 shows a screen display of the measurement result in a graph. Since the result of measurements can be displayed after analyzing it in the dedicated maintenance train vehicle, it is immediately possible to grasp the situation. It is also possible to manage the result of measurements based on the accumulated data by using the installed monitoring equipment on the ground in an office. Based on the accumulated past and current data, it is possible to make a chronological comparison of the data that reveals how the crossing wire condition is changing.

Fig. 8 Screen Display of Measurement Result in Inspection Report Format

Together with the measuring conditions and various factors of data, the measured results of crossing wire inspection are displayed.

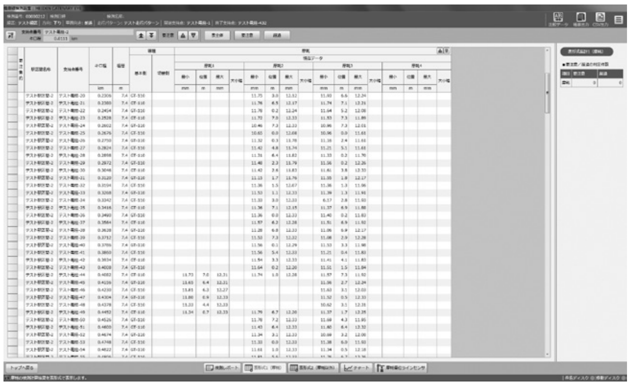

Fig. 9 Screen Display of Measurement Result in Spreadsheet Format

The measured results are compiled for each defined span and displayed in a spreadsheet format.

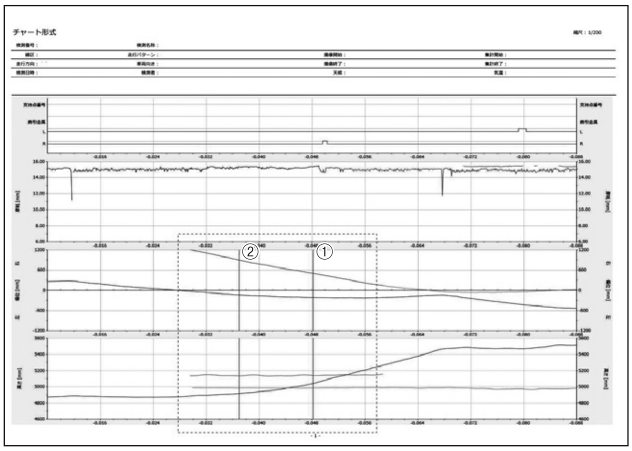

Fig. 10 Screen Display of Measurement Result in Graph

Based on a crossing wire, an example of the measured results on two "non-crossing" crossing wires are shown in the graph. In positions where the stagger value is 500mm (①) and 900mm (②) from the center of crossing-wire track, a difference in height of main-line contact wire and crossing wire is calculated.

6 Postscript

The crossing wire inspection systems for high speed railway introduced in this report were supplied for the three branch offices (Omiya, Sendai, and Morioka Branch Office) of East Japan Railway Company (JR East) in Japan. The test running period was already completed main line near the Koriyama station. This equipment will be used to inspect the construction alignment or current status condition of the crossing wire for high speed railway like the Shinkansen Line. We expect efficient measurement of crossing wires by this equipment.

Lastly, for the commercialization of this inspection equipment, we received valuable advice and help from project-related people at JR East. We would like to express our gratitude for your kind support.

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