Development of a Visual Measuring System for Pantograph Contact Strips

Addressing the need for a low-cost measuring system for pantograph inspection and maintenance, we developed a visual measuring system for pantographs. The system employs two digital cameras for three-dimensional analysis to measure pantograph contact strip thickness. Initially, measurement was conducted in a laboratory from a distance of 4 m, where it was found that it is possible to measure the thickness of the contact strip with margin of error of less than 1 mm. Currently, the system is being tested in a train maintenance depot.

Keywords: Measuring system, Stereo camera, Image processing, Pantograph contact strip, Wear

1 Introduction

High-level image processing can now be done at lower cost than ever thanks to increased performance of electro-optical components and increased data processing capabilities. At the same time, further cost reductions are demanded in rolling stock maintenance. In light of that, we developed a visual measuring system for pantograph contact strips, on which further improvement can be expected in the future. Basic tests were conducted by a stereo camera format that uses two digital cameras, and we confirmed the system's ability to measure pantograph contact strip thickness with an accuracy of 1 mm at a distance of 4 m. In order to confirm measuring accuracy on actual contact strips in an outdoor environment, we produced a prototype to be set up in the field, installed that at the wayside by the entrance to a depot, and conducted verification of measuring accuracy.

2 Development of the Measuring System

2.1 Principles of Measurement

Fig. 1 shows the positions of cameras in three-dimensional measurement and the positional relation with arbitrary point P as well as related parameters. Coordinates are found by calculating parallax from the comparison camera based on the reference camera. Three-dimensional calculation is processing to calculate three-dimensional coordinate value P (X, Y, Z) from two-dimensional coordinate P (x, y) of arbitrary point P in a recorded image with reference camera lens center as the origin, and Formula (1) is derived in that processing. In other words, coordinate values X and Y are a function of Z at three-dimensional coordinate value P (X, Y, Z). Coordinate value Z can be calculated from parallax D, focal length f, and base length b.

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X = \frac{x \cdot Z}{f} = \frac{x \cdot b}{D}, \quad Y = \frac{y \cdot Z}{f} = \frac{y \cdot b}{D}, \quad Z = \frac{f \cdot b}{D} \quad \text{(1)}
\]

Using this model, we detected contact strip edges in the direction parallel to sleepers as shown in Fig. 2. And by obtaining the cross-sectional shape of that, we are able to use a formula to measure amount of contact strip wear. To detect the edge, we used contrast between contact strip top surface and contact strip side surface.

As a basic study, we measured from a position approx. 4 m away in laboratory measurement tests indoors using actual worn contact strips. Fig. 3 shows the test recording in the laboratory.
Results of comparing measurement results obtained by recording with physical measurements show that there is promise for being able to measure thickness of contact strips at an inspection margin of error of 1 mm or less. Therefore, we decided to develop and produce a system that can be installed at actual depots and to conduct verification of its operation.

3 Field Tests

3.1 Test Measuring System

Fig. 4 shows the installed measuring system for contact strips. The system is composed of (1) cameras for recording contact strips as stereo images, (2) sensor for detecting car body, (3) sensor for detecting pantographs, (4) lighting for illuminating contact strips, (5) antenna for reading car number, and (6) controller for analyzing images and calculating contact strip cross-sectional shape. Data obtained by the system was compared with data of physical measurements of contact strip thickness to verify measurement accuracy.

3.2 Measurement of Contact Strip Thickness

Measurement is made by the cameras, sensor for pantographs, and lighting being activated at a set time after the sensor for detecting car body detects the passing of a train. When the sensor for pantographs detects a pantograph, the stereo cameras operate simultaneously to record images. An RFID tag installed on the train is also read when the train passes. RFID tags are read by a different inspection device and are of a standard where a radio station license is not needed. Images recorded of the pantograph contact strip are processed by the controller. Fig. 5 shows a contact strip that was recorded.

The controller identifies contact strip shape from the recorded image and detects its edges. The detected contact strip cross-sectional shape is calculated three-dimensionally and its coordinates calculated. Contact strip cross-sectional shape is output from the calculated coordinates. Fig. 6 shows an example of a calculated cross-sectional shape. If, from the shape of the edges of the contact strip, a contact strip edge is found to be not smooth or if reliability of judgment is poor due to recording conditions, an image of that part and a display to urge caution are shown in addition to measurement results, and judgment is then made by humans. Note that measurement cannot be made of the part of the contact strip that cannot be recorded by the cameras due to it being obstructed by the overhead contact line, so that part is interpolated.

We found that, by using the developed measuring system for pantograph contact strips, contact strip shape can be identified at accuracy of 1 mm or less and that contact strip thickness can be measured. We will continue evaluation on change in sun position by season and impact of snow and the like, verifying contact strip measuring system operation throughout the year.

![Fig. 6 Example Results of Contact Strip Measurement (Cross-sectional Shape)](image-url)