Development of a Visual Rope Tester

Yoshiki Nota,
Yutaka Shoji,
Mitsuru Kato

Keywords Image analysis, Elevator rope, Appearance check

Abstract

The number of skyscrapers being built worldwide is increasing and high speed elevators with long working distance are becoming more and more popular. As a result, maintenance and inspection sites are required to shorten and improve their inspection work. In particular, the inspection of wire ropes is the most common method of inspection uses calipers or visual inspection. As the operating distance becomes longer, the working time also increases in proportion to the lengthened distance. It is important to note, that depending on the workers' level of proficiency, there is the challenge of human error in visual and caliper value measurement.

We, therefore, developed a "Visual Rope Tester" to automate the wire rope inspection using image processing technology. In this system, two cameras take pictures of the wire rope and the system analyzes the images. This improves the efficiency of the inspection process and reduces human error of wire rope measurement.

1 Preface

With the growing use of high-speed elevators, the time and accuracy level of elevator inspection are challenging. The market calls for the improvement of these issues. Among the multiple inspection items, the inspection of wire ropes is done by calipers or visual inspection of a service worker. Since there are many manual processes like caliper-based measurement and visual inspection, measurement errors can easily occur by service workers. The number of inspection points increase with the increase of distance in elevator operation. Inspection work, therefore, tends to take a long time.

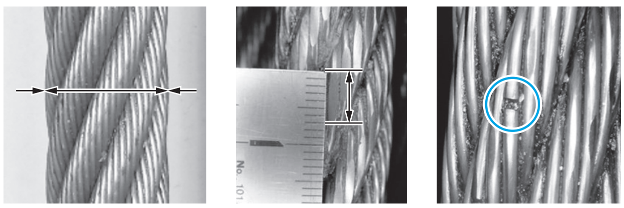
We, together with Nippon Otis Elevator Company, developed a "Visual Rope Tester" to support the inspection process. In this system, two cameras take the picture of wire ropes of an elevator in operation and the system analyzes the images. The analysis allows for quick inspections with no measurement error. In addition, the non-contact inspection improves the safety of the inspection work. In this paper, we introduce a newly developed Visual Rope Tester.

2 Inspection Items for Wire Ropes

Fig. 1 shows wire rope inspection items. These are the value of the wire rope diameter, the length of the wear mark, and the stranded wire breakage. The inspection method for each item is as follows.

2.1 Rope Diameter

While the elevator is operated, each rope wire is gradually shaved and loses its diameter. This diameter is measured with vernier calipers. Since the wire rope is a stranded wire, its surface is uneven. At the time of inspection, a service worker



(a) Diameter (b) Length of abrasion mark (c) Strand breakdown

Fig. 1 Wire Rope Inspection Items

Inspection items cover rope diameter, abrasion mark, and strand breakdown.

visually checks the point indicated by an arrow mark as shown in **Fig. 1** (a) where the diameter appears the widest. This size is measured with vernier calipers.

2.2 Length of Abrasion Mark

The length of abrasion mark caused as a result of shaving of stranded wire surface is measured with vernier calipers or a ruler as shown in **Fig. 1** (b). The measured length value is recorded.

2.3 Strand Breakdown

The strands that make up a wire rope are subject to progressive wear. The breakage of the bare wire will take place as shown by the circle in **Fig. 1** (c). At the time of inspection, the broken strands are checked by visual inspection and touch examination (palpation). After, the service worker records the number of breaks.

In wire rope inspection, since there are many inspection checking items involving visual identification and measurement by vernier calipers, inspection work time becomes longer. This becomes a factor in causing measurement errors.

3 System Configuration

Fig. 2 shows an overall configuration. This system is composed of a camera and units of control and analysis. Details of each unit are as follows:

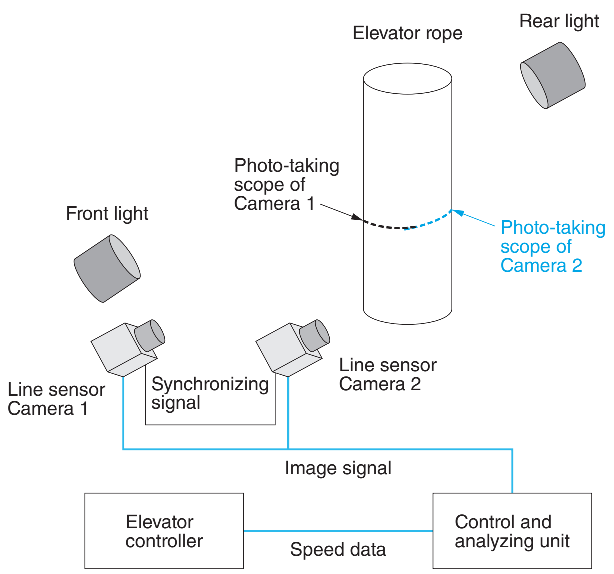


Fig. 2 **Overall Configuration**

The overall configuration of the visual rope tester is shown.

3.1 Cameras for Wire Ropes

The wire rope photo-taking equipment is composed of two (2) line sensor cameras and two lighting units. Each line sensor camera can take images at a high frequency and high resolution. When such a line sensor camera is used, it is possible to check a wire rope at the intervals of several millimeters while an elevator car goes up and down at a speed of 600 m/min. While the elevator is in operation, wire ropes cause sway and vibration. This system is, therefore, equipped with two cameras to establish a stereoscopic configuration in order to measure the width of sway caused by wire ropes in operation. Based on this measurement, impacts by sway and vibration caused while the elevator goes up and down can be corrected later in measurement and the wire rope diameter can be measured precisely.

A lighting unit used for this system is installed at two positions, front and rear, with the wire rope in between. By illuminating the wire rope from the front light, the abrasion mark length and strand breakdown can be photographed. When the wire rope is lit from behind with the rear light, a silhouette of the wire rope can be made clearer so that diameter measuring accuracy by image analysis can be improved.

3.2 Control and Analytical Unit

This equipment takes photo-taking system control and image analysis. For the control of the photo-taking system, the elevator speed data is acquired from the external elevator controller in order to control the camera's frame rate. By regulating the frame rate of the camera properly in response to the speed data, images of a wire rope can always be taken at constant intervals irrespective of the elevator speed. The analytical function part performs the image analysis.

The proposed inspection system is composed of the aforementioned two units. In many cases, applicable high-rise buildings of this system are equipped with multiple elevators in the building. For this reason, this system is made a portable type so that a single inspection system can cover multiple elevators. **Table 1** shows a comparison with a conventional inspection method. By using this system, we can realize the reduction of inspection labor hours and improvement of measurement accuracy.

Table 1 Comparison with Conventional Inspection Method

Comparison of the developed system with conventional inspection method is shown.

Conventional	Newly developed system
Positional movement 24 m/min → Measurement of a specific position	Measurement at 24～600 m/min
Measurement for each rope	Batch measurement of all ropes
Presence of individual differences in measuring positions and accuracy	No individual differences in measuring positions and accuracy
Visual checks on anomaly positions	Saved in images and post-check is possible.

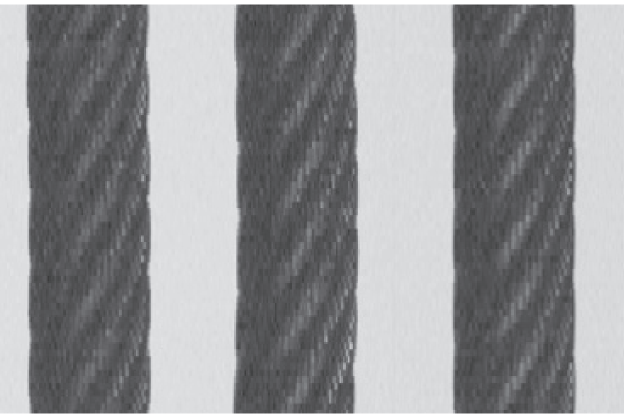


Fig. 3 Image Taken by the Tester

An image of elevator ropes is shown. It was taken by the tester at a speed of 600 m/min.

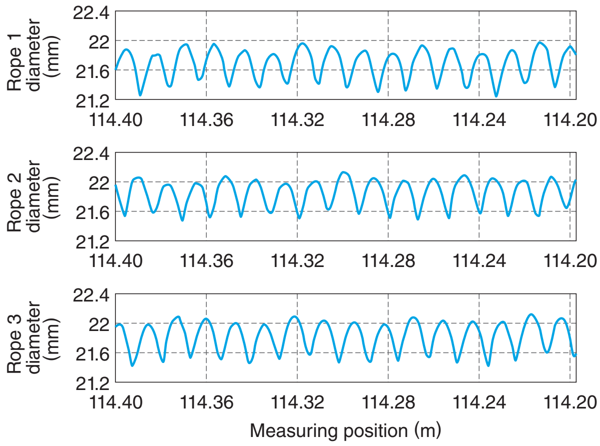


Fig. 4 Analytical Results

The analytical results of rope diameters are shown.

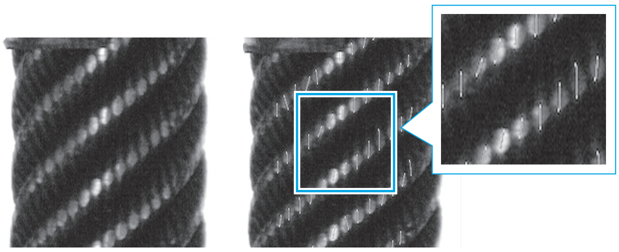


Fig. 5 Images of Abrasion Mark Analysis

Images of abrasion mark analysis are shown. The left image is taken before analysis and the right image shows the analytical result.

4 Verification Test

In order to verify the effectiveness of the newly developed system to an actual elevator in operation, the following tests were conducted.

4.1 Wire Rope Diameter Measuring Test

In the wire rope measurement test, the system was used to photograph a wire rope of elevator operating at 600 m/min and measured the diameter value. **Fig. 3** shows an image taken by the tester. Even in an elevator operating at a high speed, the wire rope can be photographed accurately. **Fig. 4** shows the analytical results. Each graph shows the diameter of each wire rope and the uneven shape of the three stranded wires are measured. We compared the system's measured value with the service worker's vernier caliper value and verified that the measurement was made within 0.2 mm of error range.

4.2 Wire Rope Abrasion Mark Length Test

For the abrasion mark length test, we photographed and analyzed an abraded rope with our system and verified the adequacy by comparing it with conventional vernier calipers values under the circumstances of assuming an elevator moving at 150 m/min. **Fig. 5** shows images of abrasion mark analysis. White dots in the left image show a trace of abrasion on the rope surface. This image was taken by illuminating the rope surface by the front light. The right image shows the result of abrasion mark measurement by actual image-based analysis. The straight line displayed on the abrasion mark indicates the measured length of the abrasion mark. According to this result, it is possible to conclude that each abrasion mark length of a rope can be detected accurately. We also tried to compare our system's measuring results with vernier calipers values and confirmed that the measurement error is within 1.0 mm.

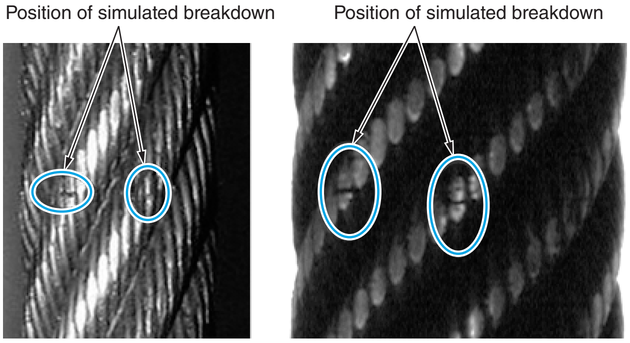


Fig. 6 Images of Simulated Strand Breakdowns

Images of simulated strand breakdown are shown. The left image was taken with a digital camera and the right image shows the result of a photo-taken with a line sensor. A strand breakdown can be photo-taken by using a line sensor camera.

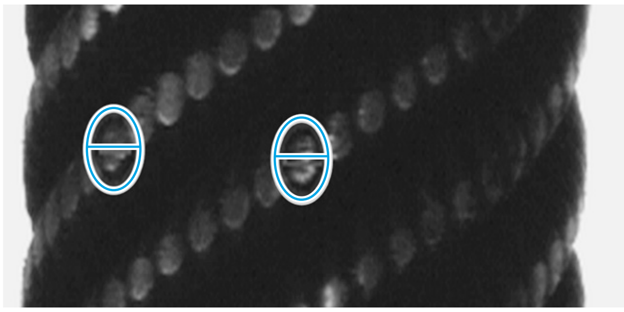


Fig. 7 Result of Simulated Strand Breakdown Analysis

The result of analysis on an image of simulated strand breakdown is shown. Circle marks indicate the positions where strand breakdown is detected.

4.3 Wire Rope Strand Breakdown Test

For the wire rope strand breakdown test, 0.4 mm tapes were placed in two positions simulating a strand breakdown assuming under the circumstance of an elevator operating at 150 m/min. For this verification, the developed system photographed the simulated breakdowns and analyzed them. **Fig. 6** shows images of the simulated strand breakdowns. The left image shows 0.4 mm tapes simulating the breakdown placed in two positions on an actual rope. The right image shows a simulated breakdown photographed by the developed system. Using this system, a 0.4 mm strand breakdown could be photographed. **Fig. 7** shows the result of the simulated strand breakdown analysis. A circle mark shows a spot where the detected strand breakdown is located. A short straight line (center line in θ) is a plot in the image domain where the breakdown occurs. In this way, a strand breakdown can be detected from an image of a rope in operation.

5 Postscript

To attain higher efficiency and improved accuracy of wire rope inspection work, we developed a rope inspection system called the “Visual Rope Tester” using the image analysis technology. With this system, wire rope diameter, abrasion mark length, and strand breakdown can be measured. As a result of verification tests of the developed system using an actual elevator in operation, we verified that the system can measure (1) the rope diameter at an elevator speed of 600 m/min and with an accuracy range of 0.2 mm or less, (2) abrasion mark length at a speed of 150 m/min and with an accuracy range of 1.0 mm or less, and (3) strand breakdown of 0.4 mm.

In the future, we intend to apply this system not only for elevators but also for other wire-rope-based products such as cranes and construction machinery.