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New Monitoring Technologies for Overhead Contact Line at 400 km·h^{-1}

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ABSTRACT

Various technologies have recently been developed for high-speed railways, in order to boost commercial speeds from 300 km·h^{-1} to 400 km·h^{-1}. Among these technologies, this paper introduces the 400 km·h^{-1} class current collection performance evaluation methods that have been developed and demonstrated by Korea. Specifically, this paper reports details of the video-based monitoring techniques that have been adopted to inspect the stability of overhead contact line (OCL) components at 400 km·h^{-1} without direct contact with any components of the power supply system. Unlike conventional OCL monitoring systems, which detect contact wire positions using either laser sensors or line cameras, the developed system measures parameters in the active state by video data. According to experimental results that were obtained at a field-test site established at a commercial line, it is claimed that the proposed measurement system is capable of effectively measuring OCL parameters.

1. Introduction

In recent modern electric railways, many countries have focused on enhancing the speed limit of commercial lines. Due to the rapid development of vehicular, track, electrical power, and signaling technologies, it is essential to evaluate and monitor the performance of trains and their infrastructure prior to commercial operation. In other words, the influence of increasing speed up to 400 km·h^{-1} must be properly assessed in order to assure passenger safety. Therefore, efficient inspection technologies have also been of interest in order to overcome the limitations of manpower caused by the complex structure and long operation intervals [1,2].

Among the numerous components of high-speed electrical railways, overhead contact lines (OCLs) serve as one of the interfaces to constantly supply power to operating trains. However, due to the physical structure of OCL, the system is exposed to various mechanical and electrical effects [3]. These influences, which represent the quality of current collection, can be summarized into major parameters such as contact force and pantograph, loss-of-contact rate, percentage of arcing, and uplift of contact wire [4,5].

Recently, the Korea Railroad Research Institute (KRRI) successfully developed a 400 km·h^{-1} class railway vehicle and its infrastructures at a commercial line (Honam Express Line, 56 km) [6]. However, due to the fact that interaction between the pantograph and contact wires causes severe vibration and rapid variation in wave propagation and reflection, performance assessment of the OCL must be strictly conducted in an extensive matter in order to guarantee that power is stably supplied to the vehicle. This paper introduces the technologies that were adopted to assess the performance of the newly developed 400 km·h^{-1} class OCL [2,6]: Specifications of the core components are verified by physical measurement systems. The paper then introduces an indirect-contact wire dynamic stagger/height measurement system that was implemented by a simple charge-coupled device (CCD) camera [7].

The rest of the paper is organized as follows: In Section 2, detailed specifications of the established field-test site are provided. In Section 3, details of the developed non-contact video-based

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measurement system are provided. Finally, the results and conclusions are organized in the remaining sections.

2. Material and methods

As mentioned in the previous section, OCL parameters must be carefully configured in order to assure the safety of commercial operation. Therefore, configuration of the core components for the field-test site was determined by the results of previous research [2,6]. Table 1 contains the design parameters that were considered for the 400 km·h^{-1} class catenary developed by the KRRI. The field-test site was established with a simple type of catenary that is composed of ultra-high tensioned contact wires. Considering that the tension and weight of contact wires are the most influential factors in assuring high-quality current collection, the catenary is composed of an improved lightweight CuMg 150 mm^2 alloy contact wire at 34 kN and a stranded CuMg 116 mm^2 alloy contact wire at 23 kN.

Performance evaluation of the 400 km·h^{-1} class OCL components was conducted by deploying HEMU-430X (standing for high-speed electric multiple unit 430 km·h^{-1} experimental) [1] at speeds incremented from 60 km·h^{-1} to 410 km·h^{-1}. Fig. 1 displays the considered OCL components along with a picture that was taken at the field-test site.

As organized in Table 2, the performance of the core OCL components is evaluated by monitoring values such as pantograph contact force, loss-of-contact rate, dynamic height/stagger of contact wires, strain, tensioning, and current. These parameters can be obtained by conducting track-side tests, which acquire measurements the moment the test vehicle passes the target location. It is determined that the OCL is reliable if all the parameters in Table 2 satisfy the permissible ranges for all considered test runs and speeds.

Table 1
Design parameters of the 400 km·h^{-1} class overhead contact line (OCL) at Honam Express Line, Korea [2,6].

Parameter	Value
Tension of contact wire	34 kN
Tension of messenger wire	23 kN
Standard span length	50/55 m
Pre-sag	N/A
System height	1400 mm
Contact wire height	5.1 m

3. Theory

In this section, the video-based dynamic stagger/height measurement system is introduced. Note that some of the details included in this paper are to organize the modules that have been separately developed in previous studies. Unlike other performance assessment measures, dynamic stagger and height can only be measured by observing the displacement of contact wire locations in reference to the center of the pantograph. Therefore, dynamic stagger and height can only be measured by a contact-less interface that captures images of both the pantograph and contact wire, as illustrated in Fig. 2. The dynamic stagger/height measurement system shares the interface with a loss-of-contact rate measurement system based on the arc sensor, which is capable of detecting electronic waves outside of the visible wavelength range.

Fig. 3 shows the video-based measurement system that was installed on the HEMU-430X, which is the test vehicle that was deployed to evaluate the 400 km·h^{-1} class infrastructure. As shown in Fig. 3, the video acquisition system is installed in the direction of the pantograph in order to simultaneously record images of the OCL.

By means of the video acquisition interface illustrated in Fig. 2 and Fig. 3, dynamic displacement (i.e., the distance from the center of the pantograph to the face of contact) can be obtained. The procedure to obtain dynamic stagger and height is provided in Fig. 4 [2,7,8]. Since dynamic displacement is calculated by the distance from the center of the pantograph, it is necessary to find the precise location of the pantograph as well as the contact wires. Therefore, from the acquired image sequence, the location of the pantograph and its center are obtained first. Then, assuming that the contact strip may not be perpendicularly aligned to the angle of the camera, the contact strip is detected in the form of a line. Similarly, a line detection method is applied to detect

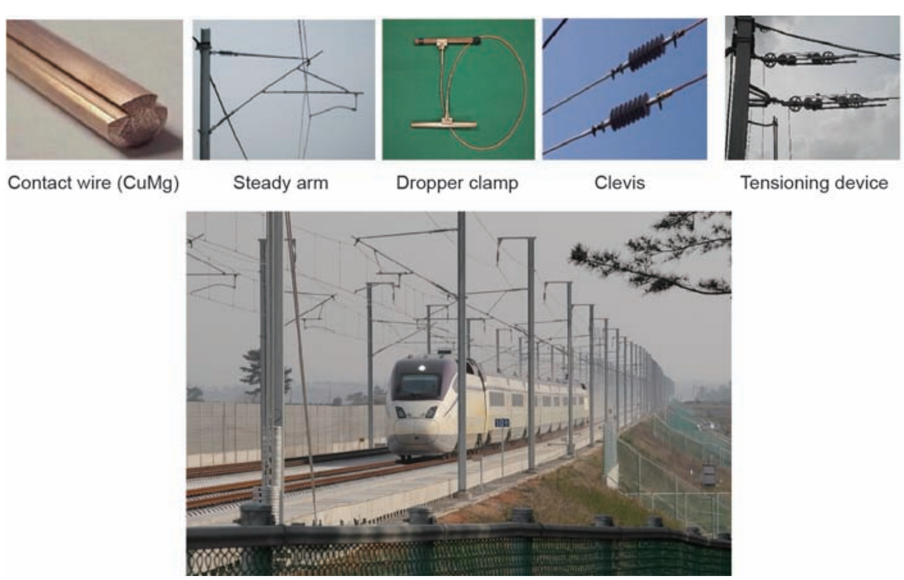

Fig. 1. 400 km·h^{-1} class catenary components and installation at the field-test site [2,6].