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Failure analysis and optimization of integral droppers used in high speed railway catenary system

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ABSTRACT

In this paper, the premature failure of the integral droppers in high speed railway catenary in China was investigated. Series of microscopic characterization and analysis were conducted to identify the root causes of the unexpected failure. By numerically simulating the existing crimping behavior, distribution of the contact stress in the dropper was obtained. It was found that there was stress concentration at the dropper sliced end, which became the primary reason for the permanent distortion and damage on the droppers, and consequently resulted in the untimely final fracture with bending fretting fatigue acting. Through the failure analysis and numerical simulation, a scheme of the improvements in measuring the existing crimping was brought up. Meanwhile, a plan was also put forward to change the current crimping model and reduce the depth of indentation of clamp tube. Static tensile tests and bending fretting fatigue tests were carried out to evaluate the optional plans, which would help extend the service life of integral dropper in practice.

1. Introduction

Being the motive power source of current high-speed trains, catenary established its position as an important component in modern electric railway systems. As an essential part in catenary, integral droppers play the role of holding the contact line and connecting it to the messenger wire, as shown in Fig. 1. Fig. 1(a) shows the position of dropper in catenary, and Fig. 1(b) displays the structure of an integral dropper, which is specially transmitting the acting force and vibration between contact line and messenger wire. Once the dropper fractures during service, the contact line will collapse and further affect the safe operation of the catenary system, and even bring immeasurable economic loss and safety threat to the humans. Hence, it is exceedingly crucial to avoid the premature failure of the droppers and improve the reliability of the catenary system. With the speed and rail mileage of high-speed dramatically increasing in China, the fracture frequency of the integral droppers increases, and dozens of integral droppers fractured every one hundred kilometers in Wuhan-Guangzhou (China) line in the past seven years. Fig. 2(a)–(e) show the failure integral droppers with different degrees of damage.

More works have been concentrated on the numerical simulation analysis of the catenary system or droppers under laboratory conditions [1–4]. For example, Fang et al. found a new algorithm for integral dropper assembly based on form-finding for cable structure and finite element method; K. Lee et al. considered that the per-sag of contract wire had an impact on the life of droppers (the more amount of the per-sag, the shorter of dropper life), and proposed a measurement model to estimate the fatigue life of

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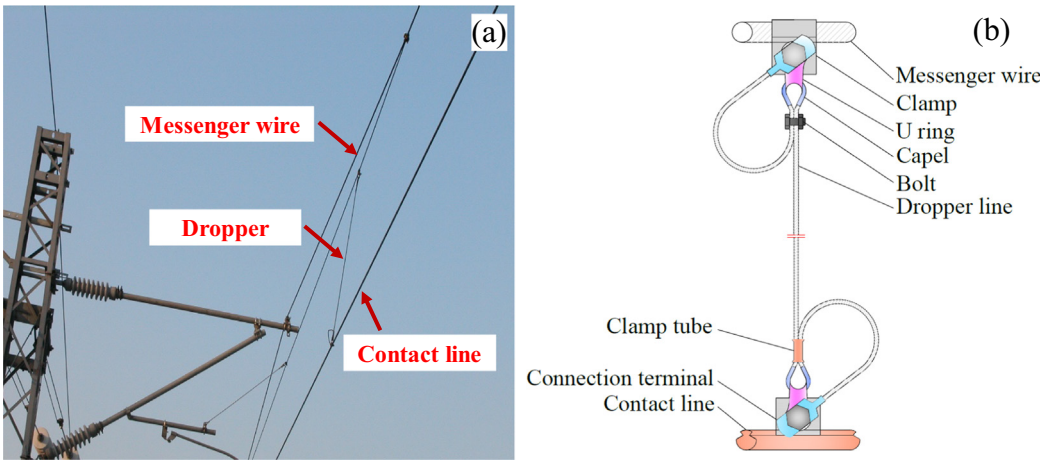

Fig. 1. The position and structure of complete set of integral droppers: (a) the position of integral droppers, and (b) the structure of integral droppers.

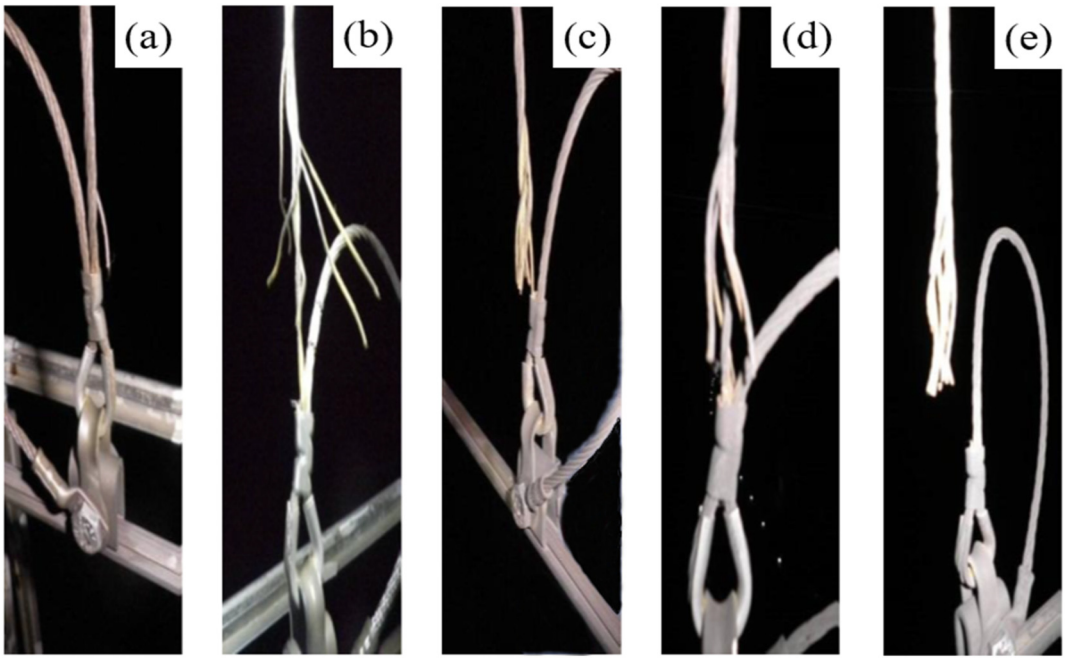

Fig. 2. The failure of integral droppers under service condition: (a)–(e) the integral droppers with different degrees of damage [8].

droppers [5–7]. Whereas a few research directly and concretely concentrated on the state of a dropper when a train is passing, not enough attention has been paid to it, leading to a lot of failure incidents of the droppers. Therefore, the root causes of the dropper failure should be carefully studied for industrial applications. Our laboratory has done many research works about the actual failure of catenary components [8], train axle [9,10] and bending fretting fatigue [11–14], which will help us to analyze this case effectively and efficiently.

In this paper, the first purpose is to explore the fundamental reasons of failure between the dropper and clamp tube; the second purpose is to extend the service life of integral droppers. A new designed integral dropper will be applied to find the better indentation depth and the crimping model of the clamp tube.

2. Experiments

In order to find out the essential cause of the fracture failure of integral droppers, the failure area of an integral dropper was cut by an electric spark wire cutting machine, as shown in Fig. 3. The macroscopic and microscopic morphologies of the failed dropper were observed by stereo microscope(SM) and scanning electron microscope (SEM, JSM-6610LV), and the chemical composition of debris