Combination of magnetic flux leakage and magnetostrictive guided wave testing method for flaws of Ferris wheel cables

Xinjun WU 1, Pengfei SUN 1, Gongtian SHEN 2

1 School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, China
2 China Special Equipment Inspection and Research Institute, Beijing 100013, China

Abstract
The Ferris wheel cable should be tested for its safety. In order to meet the requirement of the static Ferris wheel cable testing condition, a wireless climber with the magnetic tester is developed. In order to test the anchorage zone of the cable, the Hall sensor used in the magnetic tester is replaced by the coil while the magnetizer remains unchanged. Based on the magnetostrictive and its inverse effect, the magnetostrictive guided testing system is developed to test the cable anchorage zone. Due to sharing the magnetizer, the non-blinding non-destructive testing (NDT) method for cables is proposed. The magnetic testing method can scan along the cable with the high precision testing results and usually require complicated auxiliary apparatus. The magnetostrictive guided testing method can rapidly detect flaws of cables, but its signal interpretation requires complex knowledge. Finally, the effeciveness of the combined method is verified by the experiment.

Keywords: Non-destructive testing, Ferris wheel cable, magnetic testing method, magnetostrictive guided wave testing method.

1. Introduction

Ferris wheels become more popular nowadays in some scenic regions or cities. There are more than 35 Ferris wheels with higher than 50m in China [1]. It becomes the landmark of some cities, such as the EYE of Tianjin, one of the north cities in China. The flexible cable is adopted in the large Ferris wheels due to its high strength and light weight. As one of the key component of the Ferris wheels, it is important for its safety to adopt suitable method to test the cable.

There are many methods can be used to test the cables in other areas, such as the mine industry. The magnetic testing method is used to test wire ropes [2, 3]. In this condition, the wire rope tester only is fixed one appropriate position because the wire rope is driven by the elevator. It is pulled through the tester and examined. The magnetic tester must be moved by the climber because the Ferris wheel cable is static as the bridge cable [4, 5]. Furthermore, the magnetic tester cannot arrive at the anchorage zone between the wheel edges and the cable, which maybe the most serious parts. Therefore, the Hall sensor used in the magnetic tester is replaced by the coil while the magnetizer remains unchanged. Based on the magnetostrictive and its inverse effect, the magnetostrictive guided testing method can be used to test the cable body and its anchorage zone [6, 7]. Due to sharing the magnetizer, the non-blinding non-destructive testing (NDT) method for cables is proposed in this paper. The climber with magnetic tester can inspect the cable body while the magnetostrictive guided wave method is used to rapidly detect the cable body and especially to inspect the anchorage zone.

2. Principle of combined magnetic and magnetostrictive guided wave testing

Figure 1 shows the principle of the magnetic testing of cables usually employed. The magnetizer, consisting of the back iron and the permanent magnets, magnetizes the cable to suitable static magnetic field. If there is a flaw existing in the cable area being magnetized,
there will be a leakage magnetic field. The Hall sensor can be used to measure this field. By analysis of the electronic signal transformed by the Hall sensor, the information about the status of the cable can be obtained. In order to detect the whole cable, a climber is needed.

![Figure 1. Principle of the magnetic testing of Ferris wheel cables](image1)

From another point of view in measuring the magnetic field, if the Hall sensor can be replaced by the coils, and in the further when the coil, which calls the transmitter coil, are excited by the alternative current, the guided wave can be generated due to the magnetostrictive effect. The reflected wave, which maybe produced by the flaw, can be detected by another coil, which calls the receiver coil, due to the inverse magnetostrictive effect. Figure 2 shows the principle of the magnetostrictive guided wave testing. The whole cable can be scanned rapidly without moving the sensors using the magnetostrictive guided wave testing method. Furthermore, it is especially suitable to test of the flaws in the anchorage zone which can’t be detected by magnetic testing methods.

![Figure 2. Principle of the magnetostrictive guided wave testing of Ferris wheel cables](image2)

3. Instrument and system development

Based on the previous principles, the combined the magnetic and the magnetostrictive guided wave testing systems are developed for Ferris wheel cables. Figure 3 shows the schematic diagram and photograph of the combined testing system and its sensor. The magnetic testing system can detect one broken wires or 1% cross-sectional area loss. The magnetostrictive guided wave testing system can greater than 30m in the straight cable and greater than 7m in the anchorage zones of the cable with the sensitivity of 5% cross-sectional area loss. The cable diameter must be from 60mm to 180mm with the PE thickness between 3mm to 20mm. Its weight less 20kg.

A sine pulse with multiple circles is generated by a generator and amplified by a power amplifier. The amplified sine pulse current is supplied to the transmitter coil. The guided waves are generated by the interaction of the alternative current and the static bias magnetic field based on the magnetostrictive effect. The receiving procession is reversible. The received voltage signal of the receiver coil is amplified by a pre-amplifier then digitized and sampled by a 16-bits data acquisition card and finally interfaced to the computer.
The magnetic tester consists of the magnetizer and the magnetic sensor. The Hall element is used as the magnetic sensor. The whole tester is moved by a climber along the cable. The climber supply power is provided by Li batteries and is controlled by a wireless controller. A photoelectric encoder is used to record the location of the robot. The electric signal produced by the Hall is firstly preprocessed and then digitized and sampled by a 12-bits data acquisition card and finally interfaced to the computer.

4. Field test

In order to test the performance of the combined testing system, the field experiment was conducted. Figure 4 shows the photograph of the field testing of Ferris wheel cable in the eye of Tianjin, Tianjin, China. The cable specification is PES7-85 with about 83mm diameter. The magnetostrictive guided wave testing was carried out firstly. Figure 5 shows the magnetostrictive guided wave testing signal. The end reflected wave can be seen clearly and there is no flaw in the detected cable. In order test the performance of the climber, the magnetic testing was carried too. Figure 6 shows the magnetic testing signal and the amplitude of signals is fluctuated due to the moving mechanical vibration at the normal range.
5. Conclusions

Both the magnetic testing and the magnetostrictive guided wave testing methods can be used to test Ferris wheel cables. Compared with the magnetostrictive guided wave testing method, the sensitivity of the magnetic testing is not related to the testing distance in the whole cable body, but the magnetic tester has to move along the cable body and arrive at detected locations. Therefore, the magnetic testing may be rather time-consuming requiring complicated auxiliary components such as the climber. But the signal interpretation of magnetic testing is
simpler. Usually, the magnetostrictive guided wave testing method is firstly used for rapid scanning the cable body. The magnetic testing system may be used for accurate detection if the abnormal signal appears in the guided testing of the cable body. But for the anchorage zone, only the magnetostrictive guided wave testing can be employed.

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References