Experimental Study on Cable Guided Wave Non-Destructive Testing of Long Span Bridge

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Abstract. Present status of NDT technology for cables and suspenders of long span bridges is introduced in this paper. The principles, advantages and disadvantages of various testing technologies for parallel wire stayed cables are described. An experimental study was carried out for non-destructive testing using guided wave technology. It is clear that the feasibility of guided wave technology be applied to cable detection. A clear proportional relationship between detection defects and signal response is defined.

1. Introduction
Cable stayed bridges, suspension bridges and arch bridges are widely used for long-span bridges. Parallel cable stayed cables are widely used in cable-stayed bridges, and cable stayed cables are seldom used nowadays. The main cables of suspension bridges are usually composed of parallel strands of steel wires, which transmit the force between the deck and the main cable. Sling is usually made of wire rope or parallel wire rope, less steel strand. For underpass and mid-through arch bridges, parallel steel wire suspensions are mainly used to transfer the main arch and deck load. This paper mainly discusses the non-destructive testing technology of parallel wire rope.

2. non-destructive testing technology for parallel wire rope
The research on detection and monitoring technology of cables and slings is summarized as follows: The corrosion of cables is mainly detected by means of ultrasonic, magnetic, video and radiation. Practice shows that these methods have certain effect on the cable body, but for the defect of anchorage section, the above methods need to be improved.

Ultrasonic is used to detect the anchorage zone of cable support system. The ultrasonic probe is used to emit high-frequency stress wave at the end of steel wire in Anchorage zone. In a certain length range, such as steel wire corrosion or wire breakage, the ultrasonic probe will accept and display the reflected wave through the instrument to determine the defect or damage of steel wire. The ultrasonic method has high reliability, but it needs to open the anchor head when testing, which causes great inconvenience in application.

Based on the magnetic principle of wire rope detection technology began to develop, countries have successively developed electromagnetic non-destructive testing instrument for wire rope. At first, the instrument was used for defect detection of steel wires such as mines and elevators. This method is
suitable for detecting and identifying cable body defects. But the instrument based on magnetic principle have a great limitation, that is, because of the influence of geomagnetic field, the instrument has a long blind area at both ends of the pull/sling, and the anchorage area is just in the area that the instrument can not detect.

Radiography is also used for non-destructive testing of civil engineering, generally using X rays and gamma rays. There are no reports of radiographic testing for anchorage zones in the country. A clear anchorage zone image has been obtained by some scholars. The cost of radiographic testing is very large, and it takes a long time, which limits the wide application.

The electrochemical noise method is also applied to the monitoring / detection of corrosion and stress of the slings / suspender. When the stress is less than the material's yield strength, the potential noise is independent of the stress, but when the stress is greater than the material's yield strength, the amplitude of the potential noise increases with the increase of the pressure. It is revealed that the electrochemical noise is caused by the fluctuation of carbon steel rate on the electrode surface.

Resistance probe technology has the characteristics of intuitive principle, stable and reliable data, and is widely used in the detection of various corrosion media. In recent years, it has developed rapidly. Advanced resistance probe technology has been developed abroad from the 1950s to the 1960s. In recent years, resistance probe technology has also been used in the field corrosion monitoring in China.

Based on the magnetoelastic effect of magnetic flux detection technology, the principle is for ferromagnetic materials in the magnetic field, when the material properties, cross-section changes, the response of the magnetic field is also different. According to this characteristic, we can check the magnetic field characteristics of each part of the cable body in the length range, and get the disease changes of the cross section by comparative analysis. However, the application of this technology must be equipped along the cable, or manpower or mechanical equipment driven, the detection efficiency is low, and can not detect the anchor head and cable anchor joint.

Magnetostrictive guided wave technology is a new technology based on magnetic field technology. In this method, the metal material in the magnetic field is excited by ultrasonic vibration, or by longitudinal wave or torsional wave. When the ultrasonic wave propagates in the rod-shaped object, it reflects the echo when the cross-section changes, and then converts the response of the magnetic field to the electric signal for analysis. This method has been widely used in the field of pipeline inspection. It can be used to detect corrosion and interface defects of pipeline. The detection error can be less than 1%~2%. This technique only needs to install excitation and acquisition devices at a certain part of the whole rod-shaped component to detect the whole length. The detection of the anchor head and the joint of the cable and anchor of the cable structure also has the advantages of congenital principle, high detection efficiency and comprehensive detection range. At present, this technology has not been widely used in the field of bridge cable testing, but some universities and research institutions have carried out part of the model test.

3. Comparative Analysis of Detection Techniques

The technology applied to suspender detection is investigated and compared. As shown in Table 1.

| Detection technology | Technical principle | technical characteristics |
|----------------------|---------------------|---------------------------|
| Damage detection     | Open the hanger protective cover through mechanical breakage, observe the disease with naked eye or endoscope. | The inspection is very direct, which can effectively distinguish the internal defects of the hangers and damage the hangers themselves. |
| Ultrasonic           | Similar to metal defect ultrasonic testing, ultrasonic wave propagating | Commonly used metal defect detection technology is mature in |
reflection signals in metal to identify defects. By wrapping the coil outside the sling, the coil moves along the suspender and identifies the suspender disease according to the change of magnetic field signal. The magnetic field excitation is produced in the winding coil which is fixed on the surface of rod-like object, and the guided wave is transmitted along the suspender by the wire excitation inside the suspender, and the defect reflection is recognized.

Magnetic flux

guided wave

Defects can be identified by reflecting signals at different locations of the suspender. They need to be moved along the suspender and are susceptible to environmental impact. The position of the anchor head can not be detected. Fixed at one place of the suspender, the whole length of the suspender can be detected, including the anchor head, without moving along the suspender, and the detection efficiency is high. However, the loss of guided wave is large and the detection length is limited.

4. Experimental Research on Guided Wave Detection

Magnetostrictive guided wave is to use the magnetostrictive characteristics of the steel wire itself in the suspender to excite the ultrasonic guided wave and propagate along the suspender with the integrated probe of transmitting and receiving. When the guided wave encounters the defect and the end surface, the reflected echo will be received by the probe, and the position and size of the defect can be judged by the echo.

Testing objects: anchor rod, prestressed steel bar, steel strand, steel wire rope, suspension bridge main cable, PE sheath hanger, cable-stayed bridge common bearing components.

Expected targets: 1) the development of special testing prototype, integrated probe and PC terminal control software. 2) to realize the scanning and positioning of the interrupted wire defects of the existing bridge cable components. 3) quantitative detection of defects in existing bridge cable members.

The inspection hanger explains: PES7-037 Diameter of inner core steel wire, 7mm, 37 wire, 5m, 2 layer PE.

Defect description (a total of 3 broken wires), as shown in Figure 1: 1) 2 meters away from the left end, broken wire 1; 2) 3 meters away from the left end, broken wire 2; 3) 4 meters away from the left end, broken wire 1.

Figure 1. Test Cable
Figure 2. Test Cable
Sensor fixed position, defect signal detection, sensor position D = 1 m, directional right side excitation and reception. Verify the effectiveness of defect detection.

Figure 3. Test signal
Signal description: 1 is 1 broken wire defected. 2 is 2 broken wire defected. 3 is 1 broken wire defected. 4 is right end.

Experimental conclusion: The sensor is directed to the right side, and the broken wire defect and the right end signal can be detected. The closer the position of the sensor is, the larger the amplitude of the signal is. The attenuation of guided waves in composite structures consisting of multiple wires is larger than that of theoretical analysis.

5. Conclusions
In view of the non-destructive testing of long-span bridge cables, several technologies can be implemented at present, each has its own advantages and disadvantages. Theoretical studies and experiments show that the measured signal of magnetically guided wave technique is highly sensitive to the internal defects of cables. Magnetically guided wave testing technology has the advantages of simple installation, high testing efficiency, non-destructive testing, and can be used to detect the anchor head. For this technology in-further research, excluding various factors, can be better used for cable internal defect non-destructive testing.

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