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Research of Optical Fiber Sensing Technology in Bridge Detection

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Abstract:

Fiber optic sensing technology is a new type of detection technology that realizes information transmission through total reflection of light and photoelectric conversion. It has been used in the fields of medicine, military, communication, transportation, industrial control, scientific research, etc., especially in the field of bridges for decades.This paper summarizes the research status of optical fiber sensing technology and optical fiber in bridge detection, and reviews the application of optical fiber in bridge detection. First, this paper introduce the optical fiber technology, its working principle and application advantages. Secondly, the feasibility of optical fiber sensing technology in bridge detection is demonstrated through concrete application cases. It includes the detection of bridge structure and the detection of bridge material structure. Through the optical fiber sensing technology, this paper can detect the hidden dangers of the bridge in a timely and non-destructive manner Finally, this paper prospect the future development of optical fiber technology in the field of bridge detection.

Keywords: Optical fiber; Bridge inspection; Nondestructive testing.

1. Introduction

With the rapid development of cities and the continuous advancement of land development, the compression of urban space and maximization of resource utilization have become increasingly important. In order to connect various facilities and land, more and more bridges are built. However, traditional testing technology can no longer keep up with the pace of rapid construction of the bridge. This results in a lack of comprehensive and timely testing after the bridge is completed, thereby increasing the risk of collapse during the construction process. To solve this problem, a new technology -optical fiber sensing technology came into being. It solves the deficiency of traditional technical, such as damage to the bridge body, interference of external conditions to sensors, etc., so as to make bridge detection more efficient, safer, faster, and more accurate. During the bridge testing process, the use of optical fiber sensing technology can help detectors better grasp the quality and use of bridge structure and provide important basis for subsequent structural quality inspection and expansion. During the testing process, the detection personnel should combine the testing requirements of the bridge project to reasonably and standardize the application of optical fiber sensing technology to improve the accuracy and detection efficiency of the detection effect of the project [1].

Compared with the traditional detection technical method: installing resistance strain films in the key position of the bridge engineering, and sensing the bridge engineering, using the law of the resistance of the resistor and the change of the resistor, and then the detector data Statistics and analysis. The theoretical basis of the electrical detection technology is the response-power volume. During the detection process, the electrical signal is the transmission signal, which can realize the signal transmission through the wire. However, traditional testing technology is easily affected by the surrounding environmental factors in the construction operation of the bridge. If the water content in the air is large, the resistance will increase, which will lead to short circuit; in high temperature environments, the resistance increases, the entire equipment circuit is aging, then the entire equipment circuit is aging, then the entire equipment circuit is aging. It may cause other more serious accidents.

The optical fiber sensing technology uses optical fiber transmission. Optical fiber is used as a good carrier for information transmission. It not only has high -speed transmission speed, but also meets the advantages of high temperature resistance, corrosion resistance and long -range transmission. In practical applications, it will not be affected by complicated external environmental factors. In addition, in the actual application of the fiber sensor, it will not cause any damage to the bridge engineering. In terms of anti -interference ability, the optical fiber sensor also occupies a great advantage in the transmission medium. High sensitivity and resolution are conducive to the bridge The project conducts on -site testing [2].

2. Light Guidance Fiber Sension Technology

2.1 The principle of optical fiber transmission technology

Optical fiber conduction technology has been widely used in the fields of communications, transportation, medical care, industrial control, military and scientific research. Optical fiber is a fiber made of glass or plastic, which can be used as an optical conduction tool. Its transmission principle is through "full reflection of light", as shown in Fig. 1. Through the photoelectric conversion, the detection information of the bridge is converted into an optical signal and finally transmitted through the fiber's full reflection, and finally reached the receiver, as shown in Fig. 2. This process is fast and efficient and accurate, with small size and light weight, which can be shining in major fields. Therefore, optical fiber sensing technology is worthy of in -depth research in the direction of bridge detection.

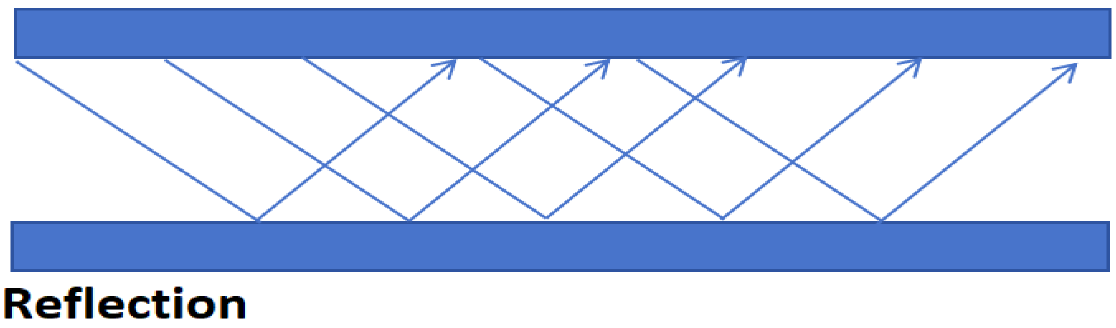

Fig. 1 Full reflection example diagram (Photo/picture credit: original).

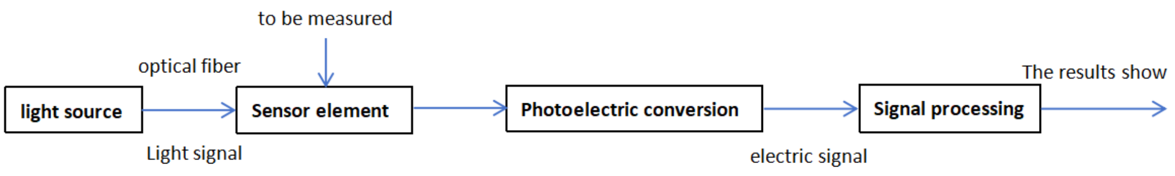

Fig. 2 Optical fiber conduction schematic diagram [3].

2.2 The application of light -guided fiber in bridge detection

In the field of bridge detection, optical guidance fiber sensing technology has been widely used, including concrete structure detection, large concrete structure testing, and bridge health detection. In practical applications, optical fiber sensor detection is mainly used. The method is to paste the light-guided fiber sensor on the surface of the structure, or embed it inside to determine the strain and damage of the structure.

A bridge near Calgary, Canada is one of the earliest bridges that use optical fiber sensors for measurement. It monitors steel enhanced rods and carbon fiber composite materials by using optical fiber sensors, and uses these sensors to monitor the bridge structure for a long time. The University of Dresden buried the optical fiber sensor into the concrete prism of the bridge, measured the basic linear response under the load, and used a conventional strain measuring instrument to compare tests to confirm the feasibility of the application of the optical fiber sensor [4].

For example, Shi Jia Jun used light-guided fiber sensors in the Lupu Bridge Health Testing Project to detect the stress strain and temperature changes of the bridge under various circumstances. This item is set to the three important steps of sensors, data measurement and data analysis, and set the optical fiber sensor to the pre -selected bridge surface, and transmit it to the bridge pipeline through fiber to achieve centralized management of the bridge. Finally, the fiber grating sensor network analyzer is used to complete the dynamic strain test of the bridge [5].

3. Structural detection

3.1 Bridge structure detection

The structure of the bridge is the most important part of the bridge safety. The quality of the structure directly determines the safety and reliability of the bridge. Through the optical fiber technology, it can be efficient, fast, and easily obtaining various information of the bridge structure, so that the bridge can be maintained and repaired even if it is maintained and renovated to improve the life of the bridge.

At present, the world has conducted a lot of research on structural detection of bridges using optical guidance fiber technology. DONG et al. used a POFS-based bridge deflection measurement system, and verified the effectiveness of the system through a series of experiments. The system consists of a connection tube and a new type of plastic fiber liquid level sensor. Discuss the basic principles, manufacturing principles and characteristics of the system in detail. Through the laboratory test, the linearity, accuracy and stability of the development system were displayed, and the deflection of the test beam was measured through the sensor, which was consistent with the results of LVTD within the range of 0.1 mm. It also discussed the impact of the environment on the system. Under different temperature conditions, stable response can be observed. The light -guided fiber sensor used changes by 1.90%between the temperature between the −5 and 40◦C, and the sensitivity of the sensor is 0.44 db/mm displacement. The system has good application potential as a powerful bridge deflection monitoring technology [6]. Cheng et al. Study the dynamic response to the train -induced mobile load induced by the train through research on a masonry bridge in Garvititt, Italy. Dynamic measurements are obtained through a distributed fiber optical sensing system, which can provide a new method for inspecting the integrity of the masonry arch bridge. The focus of this study is to use an innovative distributed optical fibrous fiber sensing technology to quantify the dynamic strain caused by quantitative trains to move the load, revealing the dynamic behavior of the masonry arch bridge [7]. TAO found that the deflection of concrete beams can cause concrete cracks and steel corrosion, which affects the use function of the structure of concrete beams such as bridges and tunnels. The distribution of distributed light -guided fiber sensing (DOFS) measured the deflection distribution of the concrete bridge structure to avoid the defects of traditional monitoring methods. First of all, analyzes the principle of measurement principle of DOFS Bourin Frequency Domain (BOFDA). As shown in Fig. 3, the arrangement and deployment of optical fiber at the bottom of the bridge concrete beam is proposed. Then, according to the distribution of optical fiber, a qualitative representation of the deflection of the concrete bridge was conducted. The results show that the deflection of concrete bridges measured by BOFDA distributed fiber monitoring technology is the same as the deflection of dial measurement. BOFDA distributed optical fiber monitoring technology can not only represent the degree of deflection of concrete bridges, but also accurately indicate the result of the deformation range and deflection distribution results that the BOFDA distributed fiber monitoring technology is effective and feasible for the deflection measurement of concrete beam bridges [8].

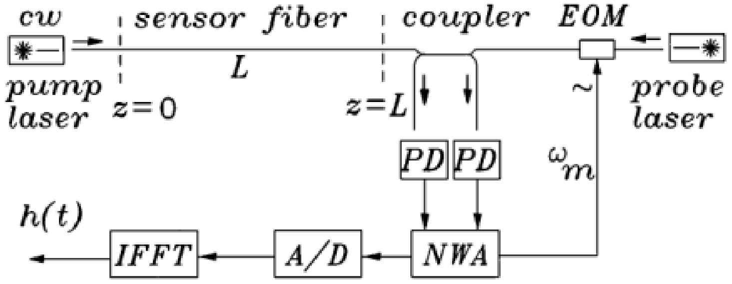

Fig. 3 Basic configuration of bofda. NWA: Network analyzer, EOM: Electric Optical Moder, PD: Optical Diodes, A/D: Simulation Digital Converter [8].

3.2 Building material structure inspection of bridge

Bridges are important infrastructure that connect two pieces of land. They are usually built over water surfaces. The erosion of the soil and water flow around the bridge foundation (pier or bridge) may cause foundation damage. Therefore, the concrete structure testing of the bridge becomes particularly important.

At present, many studies have conducted many research on the inspection of the concrete structure using optical fiber technology. Liu proposed a bridge pier for a distributed light -conducting fiber sensor that was freely installed.

By leveraging the different responses of optical fibers in water and soil, the sensor is designed in a spiral shape and attached to the pier at several bending points. Using UW-FBG technology to verify the method, distributed perception was realized. And concluded that turbulent water flow can lead to random changes in wavelengths. The change is about 0.05-0.06nm, and the sensors embedded in the soil are almost still. In Fig. 4, the temperature calibration curve washing simulation, other factors, such as loose sand and water buoyancy, interfere with the monitoring signal, but these factors are easily excluded. According to the standard deviation of the signal, the position and depth of this scour can be determined. It was found that the critical value of the signal standard deviation between scouring and non-scouring conditions is 0.002 [9].

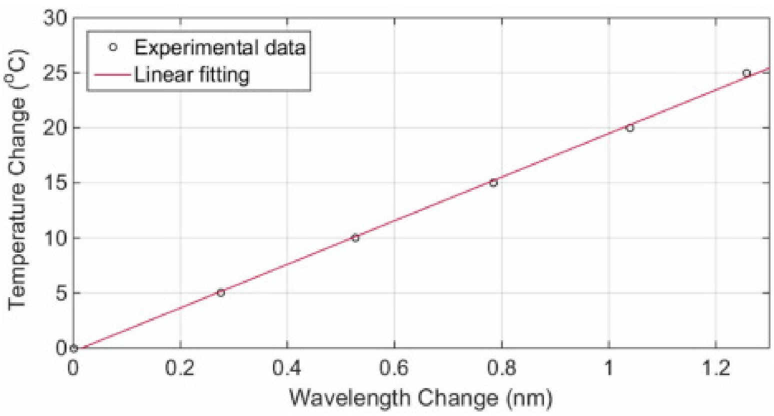

Fig. 4 Temperature calibration curve chart [9].

Stephen Young In the study, the integration of optical fiber sensors during the manufacturing process of composite material bridges was first demonstrated. In addition, a high -density fiber sensor with a special spatial resolution (5 mm resolution exceeds 20 m length) will be coupled, and high -speed response and Prague grille integration to monitor dynamic conditions is a new method. And for the first time, the comparative measurement results of HD-FOS and grating -based optical fiber sensors were recorded. Because the light -guided fiber sensor needs to monitor the inquirener connected to the on -site sensor, the study also introduced the concept of a trigger with remote wireless sensor modules with environmental conditions and collisions for the first time to obtain and monitor the optical fiber sensor data. These three main concepts are highly novel and have been proven for the first time in research. In this study, the result of using glass fiber to enhance the mezzanine or as a very light bridge. For example, if a car collision accident with a side -rail occurs, the optical fiber Prague grille sensor can provide a dynamic response of the bridge structure, and the acceleration meter response can be used to obtain power for the bridge structure. The HDFOS reaction after such incidents helps to evaluate the remaining strength of the remaining strength [10].

4. Conclusion

The application of optical fiber sensing technology in bridge detection has shown significant advantages and prospects. This article summarizes the research status of optical fiber sensing technology and optical guidance fiber in bridge detection, and focuses on its specific application of the bridge structure vibration detection and bridge material structure detection.

In the bridge structure vibration detection, optical fiber sensing technology has become an ideal detection method with its high sensitivity, anti -electromagnetic interference, durability and remote monitoring capabilities. Through the optical fiber Bourin scattering, Raman scattering, and fiber grating technologies, high -precision monitoring of the slightly vibration of the bridge is achieved, effectively improving the safety and durability of the bridge structure. The application of these technologies can not only reflect the dynamic characteristics of the bridge in real time, but also provide important data support for bridge health monitoring. In terms of structural testing of bridge materials, fiber fiber sensing technology also performed well. Using the optical fiber grating sensor and distributed fiber optic sensing technology, it can not only achieve real -time monitoring of bridge concrete structure stress, strain and cracks, but also detect the impact of the surrounding environment on the bridge itself. Compared with traditional detection methods, optical fiber sensing technology can provide more accurate and detailed detection data. This can effectively prevent and diagnose structural diseases in bridges, thereby extending their service life. In general, optical fiber sensing technology has played an important role in the field of bridge detection with its unique technical advantages, which has greatly promoted the development of bridge health monitoring technology.

Because the advantages of light -guided fiber sensing technology are great, it will not cause any damage to the structure of the bridge itself, but its overall cost is not low. The application of optical fiber sensing technology in bridge detection is becoming more and more extensive, and the amount of data obtained is increasing. How to efficiently process and analyze these massive amounts of data has become an urgent problem. In the future, this paper should focus on researching data processing and analysis algorithms to improve the speed and accuracy of data processing, so as to better support bridge health monitoring. In addition, a single fiber sensor may have limitations under certain complex conditions. By integrating a variety of sensor technologies, such as combining fiber sensors with wireless sensor networks and MEMS sensors, more comprehensive and accurate bridge detection can be achieved. In this way, the degree of application in the field of bridge detection will become infinitely larger. At the same time, it can explore its application in other aspects of bridge, such as the temperature field monitoring and corrosion monitoring of the bridge to further expand the application scope of optical fiber sensing technology. Moreover, due to its excellent performance, such as strong anti-interference ability and efficient information transmission capacity, optical fiber technology will also be widely used in other fields like communication systems, making it a future research trend. Optical guidance fiber technology allows more equipment and facilities to be comprehensively detected, making long -distance low -delay signal transmission more convenient, making our lives more secure and efficient. In short, the application prospects of optical fiber sensing technology in bridge detection are broad, but it also needs to be continuously exploring technological innovation and practical exploration. Through the cross -integration of multi -disciplinary disciplines, the further development of optical fiber sensing technology will provide more reliable and efficient solutions for bridge health monitoring, and help the safe operation and management of the bridge structure.

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