Application of optical fiber sensing technology in bridge detection

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Abstract. This paper introduces the development and application status of bridge detection technology at home and abroad, focuses on the research and application of optical fiber sensing technology in bridge detection at home and abroad, and takes strain detection as an example to introduce the detection principle, method and latest research of optical fiber sensing technology in bridge detection. Finally, the paper points out the development direction of optical fiber sensing technology in bridge detection.

Keywords: Optical fiber; Sensing technology; Bridge detection.

1. Introduction

Bridge is the economic lifeline of a country [1]. The construction and maintenance of bridge is an important part of national infrastructure construction. Therefore, the safety and reliability of bridges has become a major event related to the national economy and the people's livelihood. For a long time, electric detection method has been the main method of bridge safety detection [2]. Due to electromagnetic interference and moisture erosion, this method can not be placed for a long time. The amplified sensor is temporarily placed during detection, which not only requires a lot of manpower and material, but also specially trained engineers. At the same time, because the measured results are instantaneous and can not accurately and timely predict the working state of the bridge, the results still can not meet the needs of safety. Bridge collapses are reported every year. If long-term sensors are embedded in the bridge, the safety status of the bridge can be monitored in real time, so as to take effective measures to prevent malignant accidents. Optical fiber sensor has become an effective method in bridge detection because of its small volume, light weight, non-conductive, fast response, corrosion resistance, no interference from electromagnetic, RF and lightning current, and the unique advantages of integrating sensing and transmission [3]. Therefore, in recent years, people began to pay attention to the application of optical fiber sensing technology in bridge detection, and began to research and manufacture sensors suitable for bridge detection.

2. Comparison between electrical detection method and optical fiber detection method

The traditional bridge detection method is electrical detection method, which is to measure the strain by sticking an external resistance strain gauge on a certain part of the bridge [4]. It is based on the principle that the strain gauge is composed of a bridge structure to sense the change of the measured volume strain and convert it into the required electric quantity, so as to detect the relationship between the strain change and the resistance change of the strain gauge. The portable dynamic strain gauge DY-3 and portable super strain gauge yd-88 developed by Anshan Institute of electrical measurement technology have been widely used in the detection of many bridges in China.

Optical fiber transmission technology is a technology that uses the sensitive characteristics of optical fiber to some specific physical quantities to convert external physical quantities into signals that can be measured directly [5]. Since the mid-1970s, optical fiber sensing technology has made great progress after more than 20 years of rapid development, and more than 100 kinds of optical fiber sensors have been successfully developed. It has been involved in various fields such as national defense and military, aerospace, industrial and mining enterprises, energy and environmental

protection, biomedicine, metrology, automatic control and household appliances. The application of optical fiber transmitter in bridge measurement can realize the measurement and monitoring of the plain force of bridge steel cable and the internal stress and strain characteristics of prestressed continuous concrete beam, forming the so-called optical fiber intelligent bridge. The main difference between optical fiber sensor and traditional sensor is that the traditional sensor is based on strain electric quantity, takes the electrical signal as the carrier for conversion and transmission, and transmits the electrical signal with wires. Therefore, its use is limited by the environment. For example, too much environmental humidity may cause short circuit, especially fire in high temperature, flammable and explosive environment.

The optical fiber strain transducer takes the optical signal as the carrier for transformation and transmission, and uses the optical fiber to transmit the signal [6]. Its advantages are: the optical fiber is made of quartz glass, which is a medium and insulator, and is resistant to high pressure and corrosion, and can operate reliably in flammable and explosive environment; Optical fiber is a passive component, which has no impact on the measured object[7]; Optical fiber has small volume and light weight, and can be made into transmitter array of any shape; The carrier of optical fiber sensor is light, and its wind speed order is 1014Hz, so that the sensor has a wide frequency band, a large dynamic range and is not disturbed by electromagnetic field; It has extremely high sensitivity and resolution, which is unmatched by ordinary sensors. With the rapid development of science and technology, the requirements for the accuracy, stability and miniaturization of the transmitter are higher and higher. Therefore, phase modulation and polarization modulation sensors are the main research and development objects at present. The phase modulation sensor mainly uses the principle of optical interference to detect the signal. Due to the different structure and principle of the test device, the phase modulation sensors include Michelson interference type, Mach chender interference type and Fabry Perot interference type, as well as Bragg grating type and inter mode interference type detected by phase relationship. These sensors have their own characteristics. Today, they have begun to enter the practical research stage.

3. Development of optical fiber sensing technology in bridge detection abroad

In 1989, Brown University first proposed optical fiber sensor for the detection of reinforced concrete structures, and gave the experimental results. After that, the United States, Canada, Britain, Germany, Japan, Switzerland and other developed countries have applied optical fiber sensor technology to the safety monitoring of large civil infrastructure such as bridges and dams, and made great progress [8]. Among them, the white light Fabry Perot optical fiber sensor developed by the Canadian company is used for the internal state of the bridge structure, such as stress, strain, structural vibration, structural damage degree, crack occurrence and development, and has achieved good test results. Alavie et al. Of Smart Structure Laboratory of University of Toronto measured the stress of Beddington bridge in Canada with Bragg fiber grating sensor; Strain measurement of schiessberg Strasse highway bridge in Germany by point optical fiber sensing; In 1993, Canada pre installed the optical fiber sensor on a carbon fiber prestressed concrete highway bridge. After the bridge was opened, it continuously monitored for 8 months, measured the overall distributed strain in the concrete, processed the data with the dynamic regularization theory, and accurately and quickly evaluated the service state and service life of the bridge.

In 1996, the U.S. Navy Experimental Research Center developed the new West columbia-10 bridge health detection system, which is composed of 60 FBG (fiber bragg grating) sensors, which can realize dynamic and static strain measurement. In 1997, foster Miller Company of the United States also completed the highway bridge health detection system in Butler County, Ohio with FBG sensor. The University of Vermont in the United States cooperated with the American electro photonics company to develop an optical fiber corrosion sensing technology for detecting bridge and highway corrosion. It was first applied to three bridges in the north of Vermont in the summer of 1997 and achieved good measurement results. The Swiss Federal Institute of technology and the

Swiss intelligent structure company have developed an optical fiber strain / deformation sensor based on the principle of quasi coherent light interference. The sensor head can be easily embedded in the concrete structure or fixed outside any structure [9]. In order to compare with the traditional electrical detection technology, the intelligent structure company installed optical fiber sensor, traditional strain gauge and thermocouple strain sensor on a highway bridge near Geneva in 1995. However, only the optical fiber sensor has completed the thermal strain, load test and long-term application test of concrete curing in the whole process of construction, completion inspection and opening to traffic.

For example, the optical fiber sensor developed by rotest company based on Fabry peot white light interference principle has high precision and repeatability. It can be installed on the surface of materials or buildings or embedded in them to continuously monitor conditions such as strain, stress, displacement, crack, pore pressure, temperature, etc. If the optical fiber is used to connect the cavity with the light source and photodetector, a detection system can be formed [10]. When the optical fiber sensor is installed on the structure, the internal strain of the structure makes the cavity length of the optical fiber sensor change synchronously, so as to change the output light intensity.

4. Current situation of optical fiber transmission technology in bridge inspection in China

Since the 1990s, China has started the application research of optical fiber transmission technology. Tongji University, Chongqing University, Harbin Engineering University and other universities have carried out theoretical research on the application of optical fiber sensor in bridge detection, and have been applied to bridge detection, and achieved good results. Chongqing University has applied its research results in optical fiber sensing technology to the long-term online dynamic remote health monitoring of Qingfang overpass, which proves that the principle is feasible; Harbin Engineering University designed the optical fiber sensor based on the principle of white light interference. Different from retest, he designed the white light interferometer of optical fiber Michelson junction [11]. By comparing the optical path difference, he indirectly measured the variation characteristics of the sensor length with the stress and strain of the bridge cable. Professor Liao Yanbiao of the Department of electronic engineering of Tsinghua University has established a new wavelength interferometer experimental system. The system uses a wavelength scanning light source and two Fabry Perot interferometers with collimating structure, one as a reference interferometer and the other as a sensing interferometer [12]. Thus, a large range of absolute distance measurement is realized, and the requirements for light source stability and scanning repeatability are relaxed, so that the system has greater advantages over other existing measurement methods in the long-term monitoring of distance.

5. Conclusion

The application of optical fiber sensing technology to bridge detection has injected new vitality into bridge health monitoring and safety evaluation. After nearly ten years of research, a relatively mature technology has been formed. Its related products are favored by users because of their high precision and practicability, but its high price hinders its application in China. Therefore, in the future research, it is necessary to develop high-performance and low-cost sensors from the aspects of principle and manufacturing technology to meet the domestic market demand.

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