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Research on Data Acquisition and Monitoring Method Based on Fiber Bragg Grating Sensor

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Abstract: The emergence of fiber Bragg grating sensor and its successful application in on-line health monitoring of large structures (such as bridges, dams, petrochemical, etc.) make it possible for on-line health monitoring of gantry cranes. Distributed fiber Bragg grating sensor is installed at the key stress point of gantry crane. It is connected to the FBG demodulator in the monitoring room by transmission fiber. The signal of the sensor is processed and analyzed by signal processing system, so as to complete the functions of on-line monitoring, fault diagnosis and operation status of the equipment.

Keywords: Fiber Bragg Grating Sensor, Data Acquisition, Online Monitoring.

1. Introduction

Because of the limitation of testing technology, the resistance strain gauge, vibration wire sensor and electromagnetic testing technology were mainly used in the past, which made it difficult to achieve long-term reliable monitoring of the structural stress state of gantry crane, real-time dynamic data acquisition and accurate fault location. For many years, many other technologies of real-time monitoring of structural displacement and load state could not be used maturely. Therefore, in fact, it has been difficult to achieve the true meaning of long-term health monitoring of gantry cranes. Fiber Bragg grating (FBG) sensor is a new type of optical fiber sensor. It has many excellent characteristics such as compatibility, anti-electromagnetic interference, corrosion resistance, small size and easy reuse. Fiber Bragg grating (FBG) is a passive device with excellent performance for narrowband reflection filtering. The basic principle of fiber Bragg grating is that when the light wave propagates through the

fiber Bragg grating, the light wave vector satisfying the condition of the fiber Bragg grating will be reflected back, so that the incident grating wave vector will be divided into two parts: the projected light wave vector and the reflected light wave vector. Strain force and temperature are the most direct and significant changes in the physical parameters of FBG. When FBG is subjected to external strain force, the period of FBG will change. At the same time, photoelastic effect will lead to the change of effective refractive index of FBG. When FBG is affected by external temperature, thermal expansion will change the period of FBG, and at the same time, thermal sensitivity will lead to the change of FBG's period. Change of effective refractive index[1].Sensors based on the principle of fiber Bragg grating basically use strain or temperature to change the central wavelength of the grating directly or indirectly to achieve the purpose of testing the measured physical quantities.

Compared with the traditional electrical detection methods, the optical fiber sensor detection method has the advantages of small size, light weight, good flexibility, high temperature resistance, corrosion resistance, long service life, strong anti-electromagnetic interference ability, easy to achieve long-distance signal transmission, and is very suitable for long-term real-time monitoring of structural strain.

The portal crane health monitoring system based on FBG is still in its infancy, but its growing demand shows its market potential. Therefore, the development of a multi-channel, multi-point, high-speed and high-precision health monitoring system suitable for gantry cranes based on fiber Bragg grating sensing technology has great application prospects.

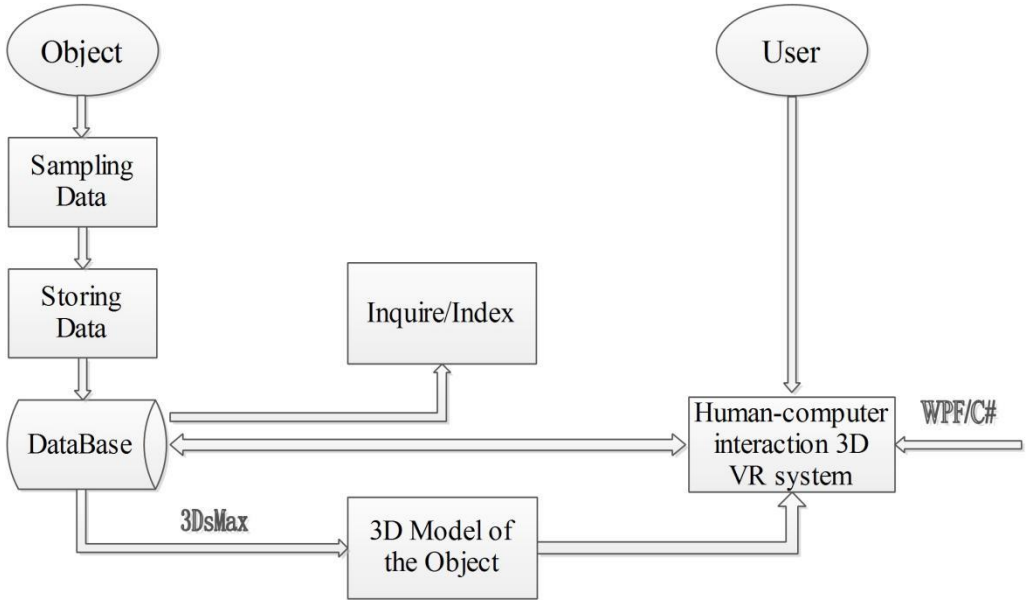

Fig. 1 System Framework Diagram

2. Data Acquisition and Monitoring Method Based on Fiber Bragg Grating Sensor

Distributed fiber Bragg grating sensors are installed at the key stress points of the monitored equipment. They are connected to the FBG demodulator in the monitoring room through transmission fiber. The signals of the sensors are processed and analyzed through the signal processing system, so as to complete the functions of on-line monitoring, fault diagnosis, running state tracking and human-computer interaction of the equipment. Line. The system framework is shown in the figure.

3. Data Acquisition and Processing

Fiber Bragg Grating Demodulation System receives and transmits the sensing signal from the fiber, including the stress and temperature values of the key stress points of the gantry crane. After photoelectric conversion, amplification and shaping, the multi-channel fiber Bragg grating sensing signal is transformed into a composite multi-channel pulse and a gate-controlled signal. The demodulation of multi-channel FBG sensing signal completes the measurement of relative pulse time of multi-channel pulse signal under the control of gate-controlled signa[2].The measurement is mainly carried out by the data acquisition module, and the data acquisition is handled by the data processing module.

According to the different measuring points, the FBG sensors installed in different forms can be divided into three types: single point, right angle and strain flower. A single point is a strain sensor at each measuring point; a right angle is two strain sensors at each measuring point, forming a right angle; a strain flower is three strain sensors at each measuring point, forming a strain flower. The data collected by FBG sensor is the strain of the measuring point. According to the strain value, the synthetic stress value of the measuring point can be calculated. The calculation formula is as follows:

(1) Single point

$$\sigma = 0.206 \times \varepsilon$$

Among them, σ For calculating the stress values at the measured points, ε Strain value of single point FBG sensor;

(2) Right angle

$$\sigma = \frac{1}{2}[\frac{E}{1-\mu^2} \times (\varepsilon_1 + \mu\varepsilon_2) + \frac{E}{1-\mu^2} \times (\varepsilon_2 + \mu\varepsilon_1)](1 + \cos 2arctg \frac{\frac{E}{1-\mu^2} \times (\varepsilon_1 + \mu\varepsilon_2)}{\frac{E}{1-\mu^2} \times (\varepsilon_2 + \mu\varepsilon_1)})$$

Among them, σ For calculating the stress values at the measured points, $E = 0.206$, $\mu = 0.3$, ε_1, ε_2 The strain values of the two fiber Bragg grating sensors consisting of

right angles are respectively calculated.

(3) Strain flower

$$\sigma = \frac{E}{2}[\frac{\varepsilon_1 + \varepsilon_3}{1-\mu} + \frac{1}{1+\mu}\sqrt{(\varepsilon_1 - \varepsilon_3)^2 + (2\varepsilon_2 - \varepsilon_1 - \varepsilon_3)^2}]$$

Among them, σ For calculating the stress values at the measured points, $E = 0.206$, $\mu = 0.3$, ε_1, ε_2, ε_3 The strain values of three fiber Bragg grating sensors which are composed of strain rosette are respectively calculated.

Data analysis and processing mainly completes the denoising, filtering and demodulation of the sampled data. The actual values of the key stress points of the gantry crane are obtained through FBG demodulation algorithm and the analysis and processing of the actual environmental parameters, which provides real-time detection parameters for the health detection of the system.

4. Diagnosis and evaluation methods

The diagnostic evaluation system is responsible for providing expert analysis according to the results of FBG demodulation and data processing, as well as the stress values of key stress points of gantry crane in actual operation. Diagnosis and evaluation is responsible for comparing the real-time data value with the real-time reference stress value, so as to give early warning and alarm under certain conditions. The real-time measurement value in the case of failure is analyzed by expert system. After expert analysis, the specific situation of the fault location is obtained.

The alarm implementation process is as follows:

(1) Fitting the threshold function of the normal operation of the equipment through the experimental data in advance. $A = f(v, m, h, x...)$ 。 The threshold function is Relevant to real-time data at work, such as speed, gravity, height, displacement, wind speed, etc.

(2) Fiber optic sensor collects real-time data when the equipment is working, and after signal processing and operation, the real-time stress value F is obtained.

(3) According to the data of other sensors on the device, the real-time data such as speed, gravity and height needed by threshold function can be obtained by signal processing by PLC.

(4) Using multi-threading technology, different threshold functions are used to collect multi-channel information. $A = f(v, m, h, x...)$ The real-time threshold A is calculated.

(5) Let the tolerance of comparison be ∂ 。 be $\begin{cases} F \geq \partial A \\ F < \partial A \end{cases}$

among ∂ The value is adjustable. In the field test, it can be adjusted according to the actual situation. ∂ Value to avoid false positives or false positives. The process is shown

in Figure 2.

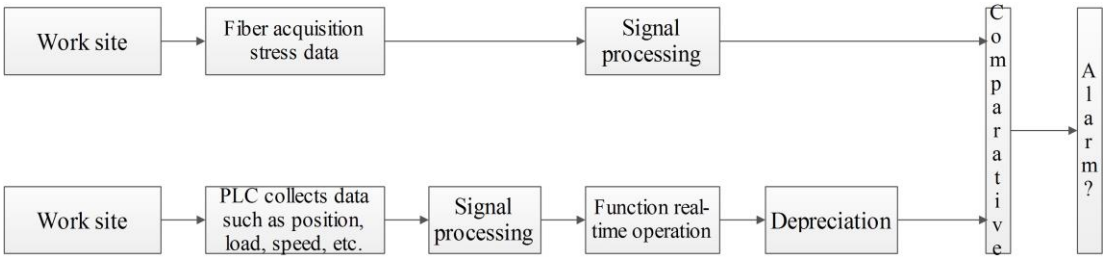

Fig.2 Alarm Execution Process

5. Conclusion

Compared with the traditional electrical detection methods, the optical fiber sensor detection method has the advantages of small size, light weight, good flexibility, high temperature resistance, corrosion resistance, long service life, strong anti-electromagnetic interference ability, easy to achieve long-distance signal transmission, and is very suitable for long-term real-time monitoring of structural strain.

In this paper, data acquisition and processing methods and state evaluation methods are studied by using fiber Bragg grating sensing technology. Fiber Bragg Grating (FBG) based data acquisition technology is still in its infancy, but its growing demand shows its market potential. Therefore, the development of multi-channel, multi-point, high-speed and high-precision monitoring system based on fiber Bragg grating sensing technology has great application prospects.

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