Design of a management system of packaged FBG sensor based on RFID for wind turbine blade

LIN Zhe-Cong, LIU Shuo-Chao, LU Meng, ZHU Ping-Yu*

School of Mechanical and Electrical Engineering, Guangzhou University, Guangzhou, Guangdong, China

*email: 2112007109@e.gzhu.edu.cn, bemail: 2112007111@e.gzhu.edu.cn

cemail: 2111807007@e.gzhu.edu.cn.
Correspondence author: demail: pyzhu@gzhu.edu.cn

Abstract: With the application of fiber bragg grating (FBG) sensors in the condition monitoring of wind turbine blades, the layout management of FBG sensors with different central wavelengths and manufacturing processes has attracted much attention. A management system of FBG sensor based on RFID technology is proposed. The management system includes three parts: packaging process of FBG sensor with RFID chip, RFID chip stored information and the FBG sensors status monitoring system, the FBG sensor installation on full scale field wind turbine blade and its maintenance. The proposed management system introduces RFID technology into the blade monitoring using FBG sensor. It provides effective digital management method for the manufacturing, the layout, the installation and the maintenance process of the FBG sensor on the wind turbine blade.

1. Introduction

As a common clean energy, wind energy is developing rapidly due to its environmental protection, renewable. However wind turbine blade (WTB) can be damaged by many aspects such as moisture absorption, fatigue. So the structural health monitoring of WTB is getting attention[1]. Fiber optic sensors have the advantages of anti-electromagnetic interference, safe use, and small size. Among them, FBG sensors, one of the typical representatives, are often used to detect strain and temperature changes during the operation of wind turbine blades. On the other hand, the FBG sensor has a slender diameter, and its own performance parameters cannot be directly distinguished by its appearance, which brings great inconvenience to the use and management of the FBG sensor.

Radio frequency identification technology, referred to as RFID technology, is a wireless communication technology that uses radio frequency signals to achieve non-contact information transmission through spatial coupling and achieve identification through the transmitted information. As long as the object packaged with the RFID chip appears in the reading and writing Within the effective identification range of the device, the reader can exchange information with the RFID chip. When producing RFID chips, manufacturers write a chip identification code (also known as UID) for each RFID chip, so each RFID chip has a unique UID corresponding to it. When the RFID chip is packaged with the FBG sensor, it is equivalent to that the FBG sensor also has a unique UID corresponding to it, which provides convenience for the identification and management of sensor parameter information.

This article proposes a wind turbine blade FBG sensor management system based on RFID technology to realize the digital management of the detection, installation and maintenance process of FBG sensors.
applied to wind power blades.

2. The configuration of the management system
RFID-based FBG sensor management system for wind turbine blade consists of three parts: (1) packaging process of FBG sensor with RFID chip, (2) RFID chip stored information and the FBG sensors status monitoring system, (3) FBG sensor installation on full scale field wind turbine blade and its maintenance. The first part is packaging the FBG sensor with the RFID chip. The packaged FBG sensor has the ability to store information and is the management object of this management system. The second part mainly includes RFID reader, FBG demodulator, computer and monitor, which can monitor the working status of FBG sensors and manage the stored information of RFID chip. This part is the data processing center of this management system. The third part includes the on-site installation and maintenance process of the FBG sensor, which is the application of RFID technology in the actual installation and maintenance process of the FBG sensor.

3. Packaging process of FBG sensor with RFID chip
The package of FBG sensors and RFID chips is the premise of this management system. Carbon Fiber Reinforced Polymer (CFRP) refers to the combination of epoxy resin on carbon fiber through high temperature and high-pressure technology. It has the characteristics of high strength, low density, good plasticity and long life. Therefore, CFRP is selected as the packaging material of FBG sensor. A high-frequency flexible RFID chip with a size of 15mm×9mm is selected, and its storage capacity is 1MB. Under the conditions of setting parameters of 0.08Mpa, 120°C and 30 minutes in the hot press [2], the RFID chip and the FBG sensor are packaged between two layers of CFRP, as shown in Figure 1. After the packaging is completed, a FBG sensor with an RFID chip is obtained. The sensor can store a certain amount of data, and each FBG sensor corresponds to the UID of its RFID chip.

![Figure 1. Package of FBG sensor with RFID chip](image)

4. RFID chip stored information and the FBG sensors status monitoring system

4.1 Hardware configuration
The hardware configuration of the system mainly includes RFID reader, fiber grating demodulator, computer and monitor, as shown in Figure 2. It is characterized in that the computer is connected to the RFID reader through a USB interface. When the RFID reader is in contact with the RFID chips, the computer can exchange information with the RFID chips, and then manages or stores information that stored in the chips. The fiber grating demodulator is connected to the FBG sensors which installed on the wind turbine blade, and the optical signal of the sensors are analyzed and demodulated, converted into the strain and temperature information of the wind turbine blade and displayed on the computer monitor.

![Figure 2. Hardware configuration](image)
4.2 Software configuration

This system is mainly based on LabVIEW virtual instrument[3], and its program interface is shown in Figure 3, LabVIEW has the characteristics of strong visualization, high flexibility, and simple operation.

![Figure 3. Program interface](image)

The RFID chip stored information and the FBG sensors status monitoring system consist of three modules: (1) the chip information writing module, (2) the sensors status monitoring module, (3) the database storage module.

The chip information writing module requires the operator to input the sensors’ parameters including FBG sensor model, center wavelength, bandwidth, production date, last update date, frequency of replacements, operator name, installation area into the computer and then write into each FBG sensor through the RFID reader. After the writing process is completed, the computer records the UID and installation area of each sensors above. Then, according to the recorded installation area, the FBG sensor is divided into three areas, A, B, and C. In each area, according to the center wavelength of each sensors, a coordinate position information is assigned to each sensor and written into each sensor’s chip. As shown in Figure 4, the coordinate position information is used to accurately install the sensors on the wind turbine blade.

![Figure 4. Schematic diagram of FBG sensors layout](image)

The function of the sensor status monitoring module is to display the analyzed and demodulated FBG sensors data on the monitor, and obtain the strain and temperature information of each area of the wind turbine blade.

The function of the database storage module is to save and upload the parameter information of the FBG sensors to the database[4]. In the local area network, the database allows multi-terminal user access to view or manage the parameter information of the FBG sensors. This article selects a database based on SQLite[5]. After terminals establishing a connection with the SQLite database, the parameter information of the FBG sensor on the terminals is synchronized with the information stored in the database through SQL statements.
5. FBG sensor installation on full scale field wind turbine blade and its maintenance
The FBG sensor described in this article is embedded or pasted on the surface of the wind turbine blade, so the sensors need to be installed or maintained during the usage. Using the feature of RFID chips that can store information, the RFID chip packaging in the sensor can be read and recognized during the installation and maintenance. The required sensor can be quickly identified. Since the coordinate position information of the FBG sensor on the wind turbine blade has been set before, after the installation or maintenance is completed, the RFID reader is used to scan the FBG sensor sequentially, and the coordinate position information is compared with the installation position sequence set in the database. The comparison automatically determines whether the sensor is correctly installed in the designated location, which can effectively shorten the time required for subsequent calibration and improve the efficiency of installation and maintenance. After the correct installation is completed, the RFID reader uploads the date of the installation or maintenance, the operator, and the frequency of replacements to the database, and updates the data parameters of the FBG sensor in the database in time.

6. Conclusions
The technology of packaging RFID chip and FBG together provides the possibility for the application and management of FBG sensor on the wind turbine blade. The manufacturing process of FBG sensors and its layout on the wind turbine blade can be written into RFID chip in the early stage, and users can quickly install FBG sensor on site by reading RFID chip. The management system can realize the real-time data sharing among multiple terminals, effectively improve management efficiency and timeliness, and promote the intelligent management for the operation and maintenance management of FBG sensors on the wind turbine blades.

Acknowledgements
This work was supported by the National Key Research and Development Program of China (Grant No. 2018YFB1501201).

References
[1] Daejhoong Yun, HeeChang Lim. (2013) Study of the damage monitoring system on wind turbine blades. The 2013 world Congress on Advances in Structural Engineering and Mechanics (ACEM13). Jeju, Korea, September 8-12.
[2] Pingyu Zhu, Xiaobo Xie, Xiaopeng Sun, Marcelo A. Soto. (2019) Distributed modular temperature-strain sensor based on optical fiber embedded in laminated composites. Composites Part B, 168: 267-273.
[3] Yang Lijuan. (2020) Design of fan health management system. Electronic design engineering, 28(17): 84-87. (In Chinese)
[4] Cai Wang. (2020) Application of database access technology based on LabVIEW in test system. Industrial instrumentation and automation, 2020(04): 77-80. (In Chinese)
[5] Zhang Daihong. (2020) Access database in LabVIEW. Aviation maintenance and Engineering, 2020(02): 70-72. (In Chinese)