An Industrial Perspective on the Applications of Optical Sensing Technology in selected Fields

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Abstract — A brief take on the optical sensing technology is provided in this paper with a main focus on the FBG technology. This work discusses the components that are required to assemble a proper FBG optical sensing system, namely the sensors, interrogators, signal transmission lines/cables, custom software, and most importantly, the installation work. A few key examples of work done by POFC and collaborators will be presented and discussed.

1. Introduction

The Prime Optical Fiber Corporation (POFC) was founded in 1991 and its core business had always been the development and manufacture of optical fibers for the telecommunication industry. In 2001, POFC formed its optical sensing business division (OSBU) to develop optical sensing technologies and to market and distribute optical sensing products to customers with these special needs. That effort continues on today. In this paper, the authors aims to describe the essential components of a typical FBG sensing system used in the civil engineering field as well as describing selected optical sensing installation done or assisted by the POFC team in 2005.

2. Guts of an FBG sensing System

For those customers who are new to the FBG sensing technology and not solidly equipped with opto-electro-based engineering capabilities, a full system will be needed to perform the optical sensing/monitoring job at hand. A system shall include:

2.1. Packaged FBG sensors

Intrinsically, FBG is capable of measure temperature and strain simultaneously. Extrinsically, depending on the physical quantities to be measured, different sensor packaging is available. Currently, sensors for measuring temperature, strain, displacement, vibration, bending, and angle are available through POFC.

2.2. FBG Interrogator

Like FBG sensors, the interrogator is also an integral part of the system. An FBG interrogator is able to detect wavelength variations, typically in the picometer (pm) range, arising from the intrinsic changes of temperature and strain experienced by FBG (sensors). A full range of interrogators are available include Micron Optics Inc. (USA), FOS&S (Belgium), FiberPro (Korea), and others.

2.3. Optical transmission cables

Depending on the application, regular or armored cables are used. In addition, due to the multiplexing nature of the FBG technology, each channel can house over 10 sensors conservatively, and greatly reduce the number count of cables. Prior to installation or sensor layout design, all sensors should be labeled in proper sequence to correct channels to avoid on-site confusions.

2.4. Custom software

FBG's multiplexing capabilities enable the user to design ultra-large and complex sensor networks. Different and distant sensing sites control may all be controlled through just one set of customized software. This is significant enhancement over the current, electronics-based traditional type sensor technologies.

3. Field work trials, Civil Engineering

The context below describes selected FBG sensor applications in the civil engineering area in Taiwan.

3.1. Hsin-Han Bridge, Tao-Yuan, Taiwan

A total of 26 FBG Bending gauges were interconnected to monitor the vertical deflection of the bridge under static and dynamic loading situation. A comparison test was also done with 3 sets of laser-based Position Sensing Device (PSD). A maximum of 2.2cm in vertical sinking was measured by the FBG method.

Fig. 1. Static loading test of the Hsin-Han Bridge

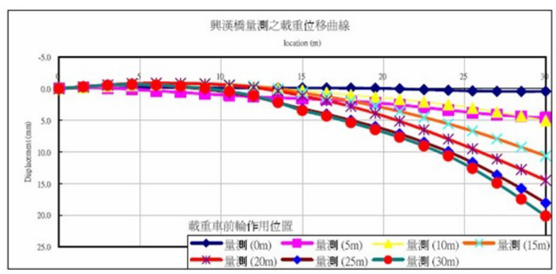

Fig. 2. Static loading test results of the bridge

3.2. Chi-San Fault, Tai-Tung, Taiwan

Fig. 3. FBG Bending Gauge installation work at the Chi-San Fault

In Figure 3, a total of 13 FBG Bending Gauges were vertically installed inside a borehole 26 meter deep. The gauges were used to determine fault variation below earth surface. Subsequent measurement indeed showed lateral changes within different earth levels.

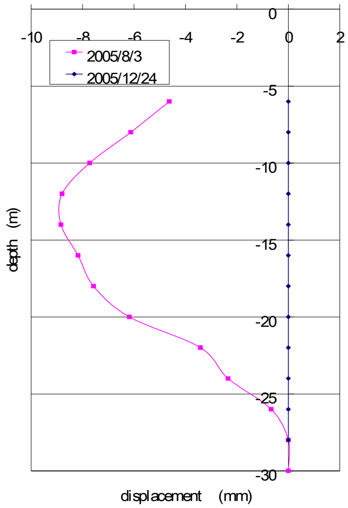

Fig.4. Fault shift observed below earth surface

3.3. Bridge girder, Kao-hsiong and Tainan, Taiwan

Inside the bridge girder, 2 sets of 12 FBG Bending Gauges were installed approximately 60 cm from the center of the girder. The sensors were used to monitor the effects of high-speed vehicles traveling on top of the bridge. Results from this dynamic test prove that the sensors were effective in monitoring vehicles with speed over 200km/h.

Fig. 5. FBG Bending Gauge layout inside the bridge girder

3.4. Ming-De Bridge, Taipei, Taiwan

Both dynamic and static results were achieved using the FBG Bending Gauge on this urban bridge. The most striking aspect is that the installation and testing were done during a rainy night. The electronic sensors originally planned were not used to avoid potential failure due to moisture.

Fig. 6. Static loading test of the Ming-De Bridge

3.5. Ai-Lan

Fig. 7. Sensor installation at Ai-Lan Bridge

This is the single largest FBG technology deployment to date in Taiwan. A total of 80 FBG displacement sensors and 14 FBG temperature sensors are to be installed during the bridge construction phase, part of the National Highway 6 System. The sensors are to be mounted on steel rebars with concrete pouring that follows. Fig. 5 depicts the bridge tower under construction and the first sensor set being installed. The bridge construction is expected to last through the year 2007.

3.6. MRT Station, Taipei, Taiwan (Work to be started)

As a research effort, a total of 23 FBG Bending Gauges will be installed inside a borehole of 46 meters in depth, as part of the retaining wall that separates the Taipei 101 Building (Currently the tallest free standing structure in the world) and the Taipei MRT underground train station. 24-hour, 365 days a year continuous monitoring will carried out using the POFC sensing system to monitor the excavation of the train station site. Results are to be compared with traditional inclinometer measurement method, with sampling rate of twice per week.

Fig. 8. FBG Bending Gauges to be installed at the MRT station site adjacent to Taipei 101

4. Applications in Other Fields

POFC's effort in FBG sensing promotion has in the past focused on civil applications. However, collaboration efforts in ship building and chemical reservoir monitoring have also evolved recently, and these new applications shall become more prominent in the upcoming years.

Acknowledgement

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