Journal Home: www.biospub.com

Popular Article

Article: RT1028

Biotica Research Today Vol 4:6 2022

447/449

How to cite this article?

Suhara and Janani, 2022. Applications of Optical Fiber in Dam Safety Monitoring. Biotica Research Today 4(6):447-449.

Applications of Optical Fiber in Dam Safety Monitoring

Shaheemath Suhara K.K.* and Janani N.

Dept. of Soil and Water Conservation Engineering, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu (641 003), India

Open Access

Corresponding Author

Shaheemath Suhara K.K.

e-mail: shaheemakaratt@gmail.com

Keywords

Dam safety, Distributed sensing, Fiber optics, Sensors

Article History

Received on: 15th June 2022

Revised on: 18th June 2022

Accepted on: 19th June 2022

***E-mail:** bioticapublications@gmail.com*

Abstract

Dams are an essential part of the irrigation infrastructure, used for water, electricity, flood control, and recreational purposes. Instrumentation in dam safety monitoring is well established. It monitors dam parameters like movements, pore pressure, uplift pressures, water level, seepage flow, cracks, stress and strain, temperature, seismic activity, and weather and precipitation. Different types of sensors are used to monitor the above parameters. These sensors modulate some properties of the light in an optical cable. Fabry-Perot sensors, Fiber Bragg grating sensors, SOFO sensors, and distributed fiber optic sensors are used in dam structural safety monitoring. In this technology, optical fiber acts as a medium for transmitting measurement information. Successful applications of optical fibers prove the maturity of this technology in the dam safety-monitoring field worldwide.

Introduction

Dams are crucial to irrigation infrastructure built across a river or stream to hold back water. Overtopping, seepage failure, and piping are the usual causes of dam failure. However, effective monitoring and maintenance can determine, amend and mitigate the problem. Nowadays, instrumentation in dam safety monitoring is well established and is used to monitor the dam parameters like movements, pore pressure, uplift pressures, water level, seepage flow, cracks, stress and strain, temperature, seismic activity, weather and precipitation (Glisic and Inaudi, 2007).

Fiber Optic Sensors

Many features offered by optical fiber sensors (OFS), *viz*., immunity to electromagnetic interference and other external perturbations, least incursive, lesser weight, multi-parameter sensing, multiplexing ability, and interrogating capabilities enable this technology to surpass conventional ones. Besides these, this technology allows the distributed monitoring of strain and temperature throughout the fiber.

Fundamentals of Fiber Optic Sensing System

The optical fiber is generally made from very thin silica. It comprises two parts, core, and cladding. The cladding has a lower refractive index than the core, which helps to guide the light into the core (Glisic and Inaudi, 2007). In addition, there are single-mode and multimode fiber optic cables, where single-mode fiber is planned for long-distance purposes and multimode for short-distance purposes. Multimode fibers generally monitor the temperature, while single-mode fibers monitor the deformation.

The optical fiber sensor techniques for parameter identification may be of four major types based on the location of the sensors in the cable, *viz*., point sensors, long sensor, multiplexed, and distributed. In the point sensing category, a sensor attached at the end of the cable senses the parameters, and the cable acts as a means of transmitting data. An example of this type is the Fabry-Perot (F-P) sensors. In long gauge sensors, the parameters are measured by optical fiber, usually along 10 cm to 10 m sections of cable, like SOFO sensors. For multiplexed OFS fiber, like fiber Bragg grating (FBG), only a few sensors are located on the single fiber. Finally, in fully distributed OFS, the fiber optic cable itself performs as a sensor, which could identify the parameters throughout the fiber.

Fabry-Perot (F-P) Interferometer

These sensors can be entrenched in dams or attached to the surface to monitor the damage, displacement, cracks, pressure, temperature, strain, *etc*. Benefits of such sensors include tiny size, less weight, zero conductivity, sudden reaction, resistance to deterioration, and immunity to electromagnetic interference. In addition, its small size enables it to be integrated without sacrificing structural complexity.

This system uses a broadband white light source rather than laser light. It comprises two semi-reflective mirrors that have a narrow gap between them and fibers fixed in a capillary tube. A portion of white light is transmitted into one end of a cable from a readout unit and travels through the F-P sensor. Some fraction of the light get deflects from the first mirror. The residual portion of light moves through the F-P cavity and reflects partially by the next mirror. These two reflected lights interfere and travel back towards a detector. The Fizeau interferometer converts the optical signal into a physical value with the help of a linear CCD (Charge Couple Device) array (Figure 1). Optical sensors based on FP interferometers are widely applied in strain temperature, pressure, and displacement measurements.

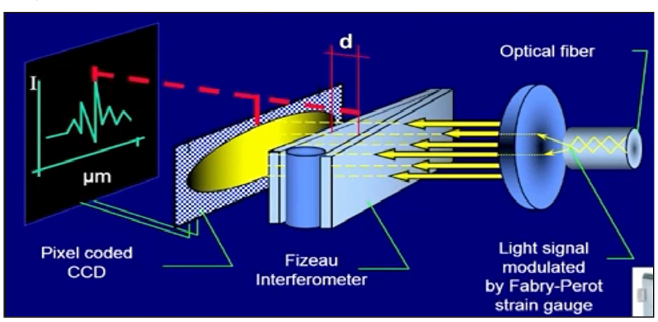

Figure 1: Fabry-Perot Interferometer

Fiber Bragg Grating (FBG) Sensors

In FBG sensors, core refractive indices vary with light properties. The significant advantages include its linear response and its multiplexing capability. Based on Bragg's law, a white light beam is encoded in the sensor. The Bragg wavelength deflects back according to a grating period when the light moves through the grating from the source at a specific wavelength. The wavelength shift changes with both temperature and strain linearly. When the grating part is subjected to external perturbation, the grating period will be changed, and the Bragg wavelength is varied accordingly. The free reference grating is required when strain and temperature changes happen concurrently, where temperature reading is used for the correction of strain values. Approximately 100 gratings can be placed along with fiber. Each grating can be differentiated using a frequency-scanning laser. Each grating performs as a point sensor.

In dam safety monitoring, an FBG sensor can be incorporated into the structure to be monitored when the dam parameters change, which consequently results in changes in the period of grating and the refractive index of the core. In addition, it causes a wavelength difference in the fiber Bragg grating signal. By monitoring this difference in wavelength, it is possible to get a dam parameter value to be measured.

The FBG sensors monitor cracks, leakage, and seepage of water. The analysis of strain sensing results shows that when peripheral leakage appears in the reservoir dam, the water will pass through the gap and cause slit flow, which causes a change in the temperature. This temperature change can be identified easily by using FBG. In addition, FBG sensors can be embedded in the structure close to the scratched zones to detect cracks. At the time of crack formation, a significant strain gradient is developed along with the sensors, which causes changes in the reflection intensity spectrum. Also, the inclinometer can be used along with high-accuracy FBG strain sensors to detect tilts. This inclinometer has been successfully installed to monitor the slope.

SOFO (Surveillance d'Ouvrages par Fibers Optiques) Sensors

The SOFO system is a fiber optic displacement sensor with a micrometer resolution range and excellent long-term stability. The system works based on the low-coherence interferometry principle to analyze the length difference between two optical fiber cables embedded in the structure.

The setup of SOFO comprises a reading unit, the fiber optic sensors, and the proper software. The sensor consists of two monomode fibers: the measurement and reference fibers. The first is in indirect contact with the structure, while the second is placed near the measurement fiber. The reference fiber is loosely attached and unchangeable with the behavior of the structure, while the measurement fiber follows the strain of the structure. The difference in length between the two fibers is analyzed to identify any structure deformation.

The Advantages of SOFO Technology

- Long gauge sensors with a gauge length of up to 10 m.
- It allows the monitoring of large structures with a few sensors.
- It can cover the whole length of the structural elements.
- Not sensitive to local defects.
- Remarkably adaptable to concrete structures.
- It can be used as an extensometer.
- It can be embedded or surface mounted.
- Temperature influences are automatically compensated for.
- Highly accurate and stable.

Distributed Fiber Optic Sensors

In distributed fiber optic sensing, the optical fiber itself acts as the sensor since the properties of the fibers vary with the surrounding conditions. The method is economically practical, and deployment is straight forward. Such kinds of sensors help to detect temperature and strain. The system makes use of Raman and Brillouin scattering of backscattered light.

The distributed sensor has the unique characteristic that it can measure physical parameters throughout the length of the fiber using a single transducer, which is impossible with electrical and localized fiber optic sensors like Fabry-Perot sensors. If the light is propagated into a fiber, some fraction of it will undergo backscattering at each point inside the fiber. This back propagated light differs from the original light launched inside. Spectral analysis of scattered light gives information about the local strain and temperature. Monitoring the scattered light helps to locate the affected areas. Figure 2 shows the working principle behind the distributed temperature sensing (Marconcin *et al*., 2018).

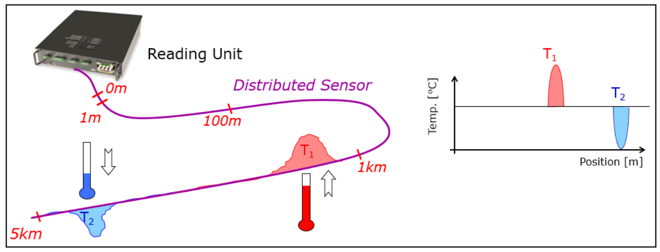

Figure 2: Schematic of distributed temperature sensor

Conclusion

Fiber optic sensor technology is one of the emerging technologies for monitoring dam safety. It helps to sense dam parameters, including deformation, displacement, temperature, and pressure in severe environmental conditions and distant monitoring. Such a type of sensor modulates some properties of the light in an optical cable. Fabry-Perot sensors, Fiber Bragg grating sensors, SOFO sensors, and distributed fiber optic sensors are used in dam structural safety monitoring. In this technology, optical fiber acts as a medium for transmitting measurement information. The number of advantages of optical fiber sensors compared to conventional systems makes them well-liked for distinct purposes. In addition, some distinctive characteristics of fiber optic sensors like multiplexing and distributed sensing open new application possibilities in the structural monitoring field.

References

Glisic, B., Inaudi, D., 2007. Fiber Optic Methods for Structural Health. John Wiley and Sons, p. 272.

Marconcin, L. do R., Machado, R.D., De Lacerda, L.A., Aufleger, M., 2018. Monitoring structures with optical fibers: Infiltration detection. *Anais Da Academia Brasileira de Ciencias* 90(2), 1865-1872. DOI: https://doi.org/10.1590/0001-3765201820170144.