

Distributed Fiber Optic

Strain and Temperature Sensing

Fiber optics is revolutionizing maintenance and operation of large structures such as bridges, levees, tunnels and buildings. Distributed sensing technology was proven in 1995 and has expanded ever since. With its ease of installation, flexibility, electromagnetic immunity, durability, and stability, optical fibers are the ideal transducer media for many applications. The great benefit is

that the fiber optic strands are the actual sensor. Each fiber offers the ability to act as many sensors (distributed sensing) making fiber optic technologies attractive for monitoring large structures. There are numerous ways to make measurements using fiber optics. This document discusses Distributed Temperature Sensing (DTS) and Distributed Strain Sensing (DSS).



Distributed Strain Analyzer

With large structures such as bridges, buildings, dams, mines, landslides, levees, tunnels, and pipelines, monitoring during construction or throughout the structure's life provides a cost effective means to identify potential problem areas and implement predictive maintenance procedures. However, many structures are simply too big to monitor with conventional point sensors. With distributed fiber optic sensing technology the entire fiber optic cable acts as the sensor. Strain or temperature can be sensed at any point along the fiber's length, typically every meter for many kilometers. With distributed fiber optic sensing, monitoring large structures without placing thousands of individual sensors is now possible. A single distributed optical fiber can take tens of thousands of measurements over great distances

either automatically or on demand. Software enables hands-free monitoring and streamlined dissemination of large quantities of data. It also can identify abnormal conditions and initiate response actions.

HOW IT WORKS

A DSS/DTS system consists of two entities:

- 1) The optical fiber sensor
- 2) The detector system which includes a light source and an instrument that measures the properties of the reflected light.

To make the measurement, laser light is pulsed through the length of fiber; as the light travels down the fiber some of that light reflects back as a result of scattering. By analyzing the return time of the light, its frequent content and its intensity, the measurement location is determined and the measurement value is derived.

There are two types of scattering analyzed in distributed fiber optic sensing:

- 1) Raman scattering is an intensity variation at a known frequency relative to the original wavelength. The Raman peak intensity is dependent solely on temperature.
- 2) Brillouin scattering is a frequency shift proportional to the original wavelength. Brillouin scattering captures both temperature and strain variations.

SPECIFICATIONS

It is possible to measure strain and temperature in a single 30 km long cable every meter, eliminating the need to place individual instruments and the associated wires at specific intervals. The larger the monitoring project, the more cost effective distributed fiber optic technology becomes.



Fiber optic cables before downhole installation at a copper mine.

APPLICATIONS

DSS and DTS are often ideal in monitoring large projects. A distributed fiber system is flexible and can be designed to meet a variety of monitoring needs. Fibers can be buried or placed in a horizontal trench to monitor a levee. They can be placed in a dam to monitor the cement

curing temperature and structure strain. Fiber cables can be trenched in a grid for detailed landslide and surface movement analysis. Fibers can be attached to well casing and then grouted into a vertical borehole to observe the effects of open pit expansion on the surrounding rock. By detecting a change in temperature via DTS, leakage from a pipeline or levee can be quickly pinpointed.

SERVICES

Applied Geomechanics specializes in integrated monitoring solutions, which include distributed fiber optic installation and monitoring and other monitoring methods. Our team of

engineers, geologists, and scientists can help design the system to fit your monitoring needs and cost objectives.

AGI bridges the gap between the geotechnical industry and fiber optic technology with our multidisciplinary team approach. We offer project management, installation, data management, graphical visualization, system maintenance, and project support services. Because DTS/DSS systems can take a measurement every meter for many kilometers, structures monitored periodically or continuously will produce a very large amount of data. AGI works with you to manage your data, integrate the data with other monitoring systems, and

produce reports that are meaningful to your specific situation.

Monitoring large projects where conventional strain gauges would be too numerous to install efficiently is now within reach. Measurements every meter for up to 30 kilometers are possible. Systems can be designed to meet a variety of needs including continuous data acquisition, threshold detection, automatic data reporting, and graphical analysis, and various other specialty serviced requirements. Applied Geomechanics encourages your inquires, challenges and applications.

DSS DSS FIBER OPTIC	
Range	80km
Strain Resolution*	30 µε
Temperature Resolution*	0.1°C
Number of Measurements	Up to 20,000 in one fiber
Maximum Strain	~15,000 µε
Spatial Resolution*	1.0 m
Measurement Averaging Time	2 to 25 minutes
Life of System	~30 years

**Measurement resolution depends on the full-scale range, spatial resolution, and measurement averaging time.*

STRUCTURE	CHALLENGES	SOLUTIONS
Bridges	Structural health monitoring and as a maintenance tool	Structural components can be monitored to determine an initial 'fingerprint' of the structure based on ambient loading conditions, and then to identify changes that may require further, detailed inspection.
Buildings	Post event analysis such as deformations and force redistribution	After an earthquake, subsidence event or during adjacent construction activity, changes in floor slab, beam and column strains can be documented to pinpoint areas for further inspection or analysis.
Dams	Seepage, voids, cracks and lightening	DSS monitors structural strain caused by settlement and crack propagation. DTS monitors leaks and seepage. During the cement curing process, DTS can help identify voids. Both DSS and DTS are immune to electromagnetic fields generated by lightening.
Landslides	Detection and understanding of movement	DSS and DTS can be attached to tubular casing and driven deep underground or placed horizontally at the surface. A grid of surface fibers can identify three dimensional movements.
Levees	Seepage and levee movement	DSS can be trenched into the levee system for kilometers, monitoring high water points areas of high strain that may be precursors to failure. DTS can monitor and pinpoint leaks based on temperature changes caused by flowing water.
Mines	Large-scale stability monitoring (examples: block caving, high wall monitoring, surface subsidence)	Mines are diverse structures with various stability challenges. DSS and DTS can be designed to meet these challenges. A horizontal cable placed near the surface can monitor surface subsidence. Cables attached to a well casing can measure in situ stress, strain, and changes in ground water temperature. Cables can be placed along or around shafts and adits to monitor changes in plinary stresses and strain.
Pipelines	Detection of leaks and mitigation of threats to pipeline integrity	DST and DSS can be used over tens of kilometers of pipeline in remote areas for leak detection and potential damage to pipelines as a result of ground movements, encroachment of right-of-way, or corrosion. This application can service both above-ground and buried pipelines.

APPLIED GEOMECHANICS

140 Chestnut St.
 San Francisco CA, 94111
 T: 1+415-364-3200
 F: 1+415-861-1448
 Geomechanics.com

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