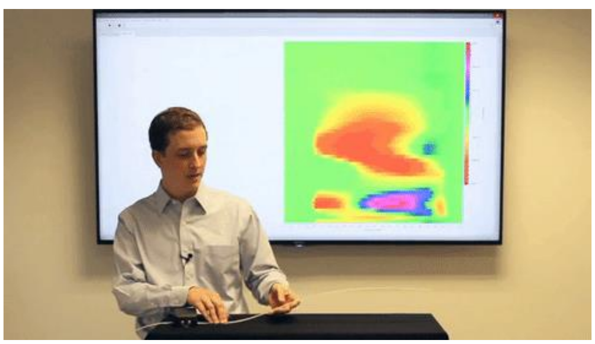
Distributed Strain and Temperature Measurement

Understanding the benefits of distributed measurement using fiber optic sensing

SENSURON
ENGINEERING AT THE SPEED OF LIGHT

For decades, point sensing solutions like strain gauges and thermocouples have been good enough for most applications of strain and temperature measurement, however, the mindset of ‘good enough’ often blocks innovation. New, robust sensing technologies that can monitor beyond the scope of point sensors are necessary to enable the next generation of designs. Fiber optic sensing platforms that obtain spatially continuous, real time data and can sense multiple parameters simultaneously can accelerate product innovation through easier installation, by collecting comprehensive data, combining multiple sensing capabilities into a single platform and more.

The limitations to point sensors are not about accuracy or reliability, rather it is about insight. Many organizations have innovated beyond their ability to test and monitor their designs. Take for example the proliferation of composite materials in the aerospace and automotive industries. Designing with new materials creates a number of design challenges and legacy technologies cannot always provide the data necessary to efficiently understand how composite components and assemblies behave under real world conditions. Strain gauges cannot collect data about how forces are distributed throughout a structure, but only give information about critical areas. In contrast, fiber optic sensing systems that can obtain spatially continuous data (distributed data) are able to monitor full strain fields and temperature gradients. By monitoring both critical points and everywhere in between, distributed strain and temperature measurements give engineers unprecedented insight into the behaviors of their designs that legacy technologies simply cannot accomplish. This paper will discuss the benefits of using distributed data for model validation, improving processes, ensuring the safety of structures, and accelerating development.



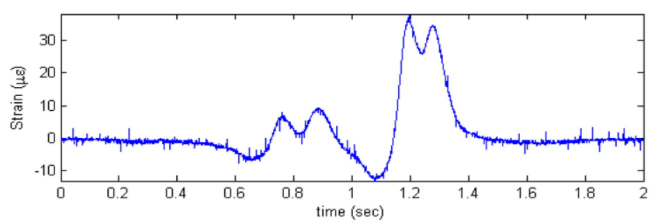


Figure 1. *The image on the left demonstrates one visualization of spatially continuous strain data acquired by Sensuron’s fiber optic sensing platforms. The x-axis represents length along the fiber, the y-axis represents time and the colors represent strain measurements. This is in contrast to the image on the right which is the strain output from a single strain gauge where one point of data is collected over time.*

Fiber Optic Sensing Basics

Navigating the fiber optic sensing technology landscape can be intimidating since there is such great diversity of capabilities within the industry. In order to properly discuss distributed fiber optic sensing it is important to understand, at a high level, the distinctions between technologies.

For a more in depth discussion of the fiber optic sensing landscape, you can download our Introduction to Fiber Optic Sensing.

Sensuron offers intrinsic fiber optic sensing technology, whereby the fiber optic cable itself is the sensor. Within the division of intrinsic fiber optic sensors, there are, generally speaking, three generations of technologies: point fiber bragg grating (FBG) based sensors, scattering and spatially continuous FBG based sensors. Scattering techniques take fully distributed measurements while FBG techniques can have a handful of sensing points or be fully distributed depending on how the system interprets the signal from the sensing element.

FBGs act as miniscule mirrors and are manufactured into the core of the fiber. As light travels down the fiber, each grating reflects a portion of the signal back to the system. The system recognizes changes in the returning signal and interprets this information to provide accurate strain and temperature measurements. Most FBG based systems have a handful of sensing points along each fiber. While this multiplexing capability was a step forward from legacy technology, it still cannot provide the sensor density required for monitoring continuous distributions Some strengths of point FBG sensors include precision, the ability to perform dynamic tests, and high speed data acquisition.

Scattering techniques do not use FBGs at all, but depend on imperfections in the fiber optic cable to attain readings. There are three different types of scattering technologies used in sensing systems today and each has different capabilities. Generally speaking, scattering based fiber optic sensing systems benefit from distributed data and long sensing lengths. They are, however, subject to low data fidelity, very slow data acquisition rates on the order of minutes, and are susceptible to vibration limiting them to static operation.

Sensuron applies a technique that incorporates the strengths of point FBG sensors and scattering based systems. Sensuron uses FBGs as the sensing element in our fiber, but inscribes them continuously along the entire length of the fiber. This, along with the technique used to interpret the signal, enables our platforms to take spatially continuous data while retaining the precision, dynamic testing, and high acquisition rates afforded by using FBGs. This allows engineers to obtain precise measurements of full strain fields, temperature gradients and other parameters in either static or dynamic environments. Using the distributed strain data provided by the fiber, Sensuron's platforms can also measure internal and applied loads, deflection, 3D shape and liquid level.

Click here and download our Introduction to Fiber Optic Sensing.

Benefits of Distributed Data

Enhance Model Validation

One of the core benefits of distributed strain and temperature data is that engineers can more efficiently and confidently validate their FEA and thermal models. By monitoring full strain fields, such sensing systems are able to determine how loads are distributed throughout a structure. This information can help engineers refine their models to avoid costly failures later in the development process or after the product has launched.

As a concrete example, Sensuron's rugged fiber optic sensing platform, the RTS125, was used in a variety of tests during the Adaptive Compliant Trailing Edge project with NASA Armstrong. The project, in conjunction with FlexSys and the US Air Force Research Laboratory, was aimed at developing and validating a design to replace traditional wing flaps with malleable monolithic structures that can change shape while maintaining a smooth surface. These new wings are estimated to reduce drag by 3-4 percent and when installed on an aircraft, could save an estimated 12 percent in fuel costs and reduce noise by 4-6 decibels.

The first step to realizing a commercially available adaptive wing is by gaining an understanding of how the structure behaves in flight. Sensuron's fiber optic sensing platform was able to provide real time strain data and information about how loads were redistributed throughout the wing during flight. In addition to using the strain and load data to validate the FEA model, this data can then be fed into a flight control feedback system so that the control system can optimize the shape of the flap in real time in order to optimize efficiency. As a result, fuel consumption and the overall operating cost of the aircraft can both be reduced.

In the automotive industry, organizations have used Sensuron's technology to validate thermal models for various critical components including routing fiber around the engine block, battery radiator and exhaust system. With temperature ranges from cryogenic temperatures up to 400 degrees Celsius, fiber optic sensing systems that take distributed temperature data offer the greatest range and flexibility of any sensing technology on the market.

Click here to read more about how distributed fiber optic sensing can help with model validation.

Improve Processes

Unlike legacy technology which only collects data at critical points, Sensuron's fiber optic sensing platforms collect fully distributed strain and temperature data. This allows engineers to observe how a structure behaves both at critical points and everywhere in between. Many of our customers have used the technology to validate their thermal or structural models or to conduct tests in conditions where other sensors cannot operate. For example, one of Sensuron's customers embedded the sensor in a composite structure during the layup process. As a result of monitoring residual strain throughout the entire component, Sensuron's device detected the presence of defects caused by objects that were accidentally embedded in the material. Strain gauges would not have detected the foreign objects unless they happened to be placed directly above the defect. In addition to helping the engineers validate their structural models for the composite part, the data from the sensor helped them improve the manufacturing process of the composite materials.

Sensuron's fiber optic sensing technology can also be used to create thermal profiles of molds during the injection molding process or dies during die-casting. Having distributed temperature data helps manufacturers understand how their molds and casts perform under different conditions and can allow them to improve their processes to avoid defects like blistering, flow lines, stringing, warping and more.

Ensure the Safety of Structures

One challenge facing Structural Health Monitoring (SHM) systems today is a lack of fine spatial resolution from sensors. Sensuron's fiber optic sensing systems help overcome this challenge by providing spatial resolution down to 6.3 mm. The distributed data provided by the system as well as real time monitoring capabilities provide a continuous monitoring solution for SHM using global vibration information. Sensuron's distributed sensing expertise and Ensyso's nondestructive damage evaluation software led to a continuous health monitoring system that detects, localizes and characterizes damage to a structure. Rather than using point sensors like accelerometers or vibration wire strain gauges that only collect points of information, asset management organizations can deploy Sensuron's technology to ensure that their infrastructure is structurally sound.

Click here to learn more about the nondestructive damage evaluation system.

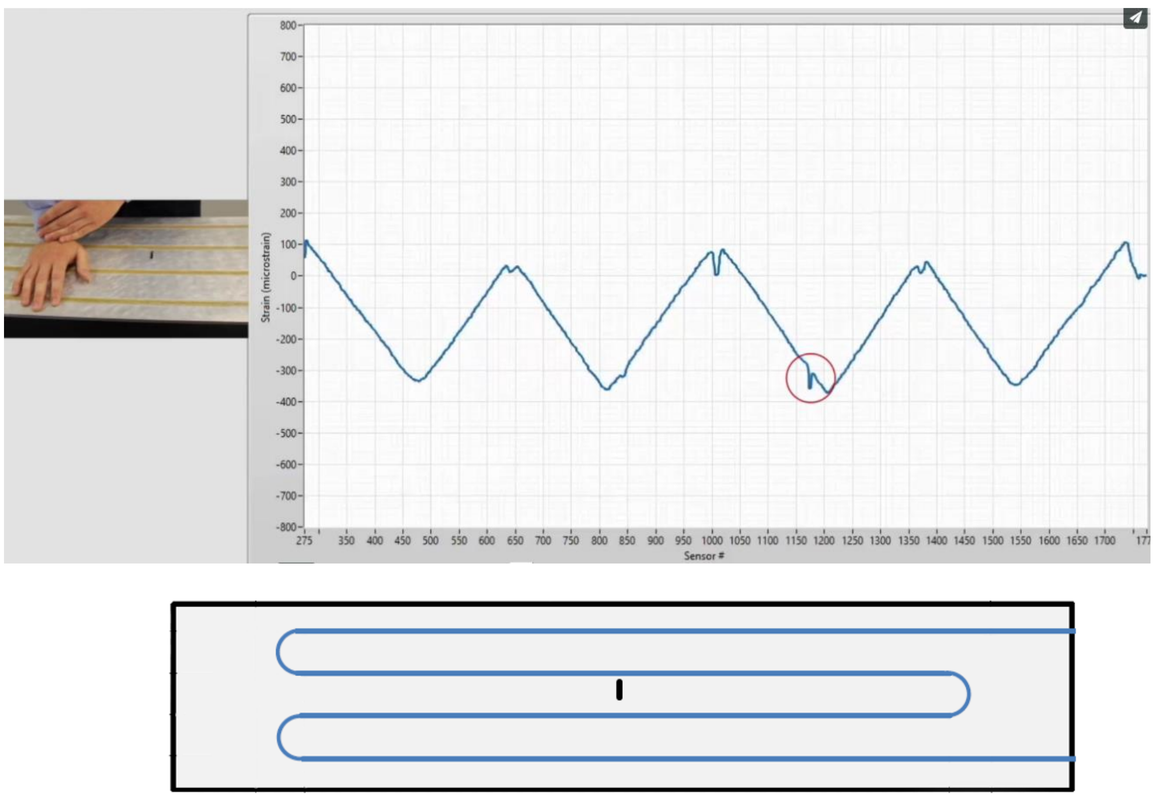


Figure 2. *The top image shows the distributed strain data from a demonstration beam instrumented with approximately 10 m of fiber. The spike inside the red circle corresponds to a strain concentration around a crack in the beam. The bottom image is a diagram, illustrating in blue, the sensing fiber layout on the beam.*

Accelerate Development

Model validation and improving processes both contribute to accelerating development, but the ability to monitor multiple parameters at the same time can significantly speed up the development process. Existing data acquisition hardware is capable of supporting multiple sensor types, however, the weight of the cables and tedious installation of sensors make legacy solutions cumbersome to deploy in multiple kinds of tests.

Multi-sensing platforms, simply put, are sensor technologies that can monitor multiple parameters (strain, temperature, deflection, etc.) simultaneously and are robust enough that they can be deployed in multiple applications across an organization and utilized throughout the product lifecycle. It's not just about being able to monitor different parameters using the same data acquisition hardware. More than that, a multi-sensing platform can consolidate sensing technology so the same hardware, with minor changes in application techniques and sensor packaging, can adapt to cover multiple testing and monitoring needs of an organization. In order to accomplish this, a sensing platform must be able to do more than just sensing more than one parameter. Additionally, the sensing system must obtain spatially continuous information in real time, be capable of taking dynamic measurements, be able to easily integrate with a network and perform well in the lab or harsh environments. These features allow multi-sensing platforms to be deployed in lifecycle monitoring applications from design validation to providing operational data for critical components and equipment.

One of Sensuron's customers used our technology to validate the performance of a monitoring system that will be deployed in harsh environments. Due to the flexibility and ease of deployment of Sensuron's sensing platform, the customer was able to conduct validation tests at a much more rapid pace than if they had used legacy sensing technologies. The increased rate of testing coupled with the distributed strain and temperature data provided by the system enabled the project to be completed an estimated two years earlier than if the test had be conducted with legacy technologies.

Final Thoughts

Armed with distributed strain and temperature data from fiber optic sensors, engineers can better validate their models, improve processes, ensure the safety of structures and accelerate development. Many organizations have innovated beyond their ability to test with legacy technologies. Sometimes it takes a significant, expensive failure to admit that this is a human issue and not a technology issue. Adopting a new technology can be daunting for a number of reasons, however, the most common reason people are hesitant to adopt fiber optic sensing is unfamiliarity with the technology. At Sensuron, we prioritize making our customers successful and can provide the education and resources necessary to understand, implement, and install fiber optic sensing technology. For additional information, you can reach out to us directly at info@sensuron.com or check out the additional resources below.

Additional Resources

Click Here
to download case studies

Click Here
to register for an upcoming webinar

Click Here
to learn more about our products

Email Us
to discuss your specific application needs