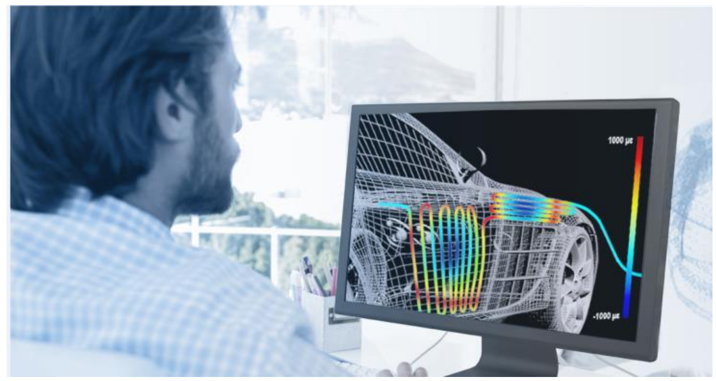
High Definition Fiber Optic Sensing (HD-FOS) – 21st Century Design Validation for 21st Century Automotive Design



Luna's ODiSI, with High Definition Fiber Optic Sensing (HD-FOS), will reduce test time while providing a new level of visibility into the structural performance of automotive frames under load. Environmental concerns and government regulations are placing new pressures on engineers to produce environmentally friendly vehicles. These pressures are driving a rapid adoption of advanced technologies across the automotive industry. To design automobiles for the 21st century, engineers will need 21st century design and validation technology.

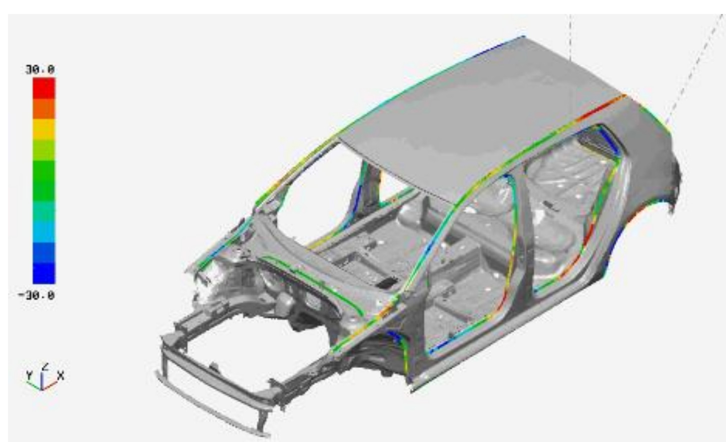
Lightweighting – Challenges for Automotive Frame Design

Reducing vehicle weight is the quickest path to higher fuel efficiency. Programs to reduce vehicle weight can manifest themselves in many ways but common to all programs will be a focus on reducing the weight of the automotive frame. Weight reduction can be achieved by adopting a combination of new design methods[1], using advanced lightweight materials, or a hybrid approach. New materials will also mean new methods to join assemblies and a greater use of adhesives[2]. **The ODiSI's high definition data and ability to reconfigure strain gage length and location through software will serve as a powerful tool for engineers seeking the optimal solution in the least amount of time.**

Body in White Test Instrumented with HD-FOS

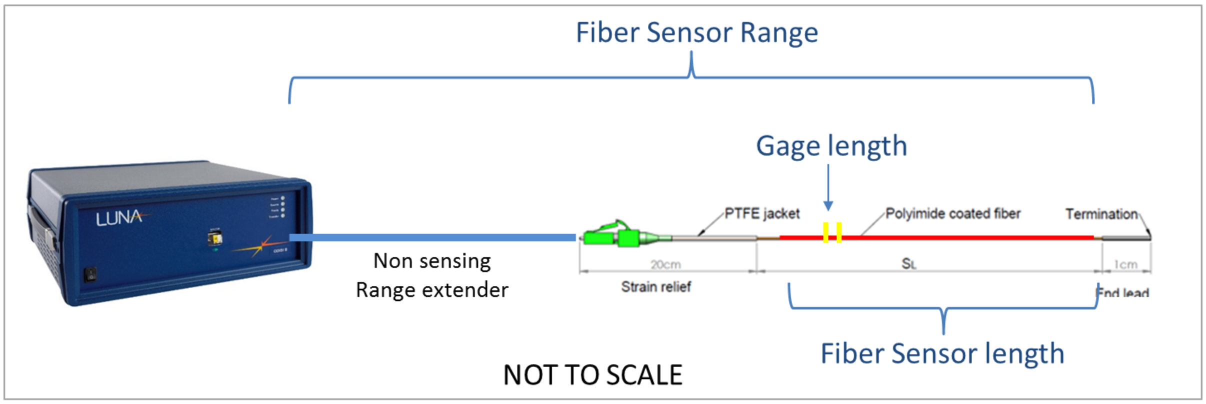
A body in white is instrumented with a 50 meter, HD-FOS sensor. The sensor is configured by software for strain gages of 5 millimeter gage length and provides over 10,000 unique strain measurements.

The sensor routing is superimposed on the 3D CAD model. A stored data file is processed with Luna's 3D visualization software, allowing engineers to see the distribution of strain as the body in white is subjected to compressive and torsional testing.



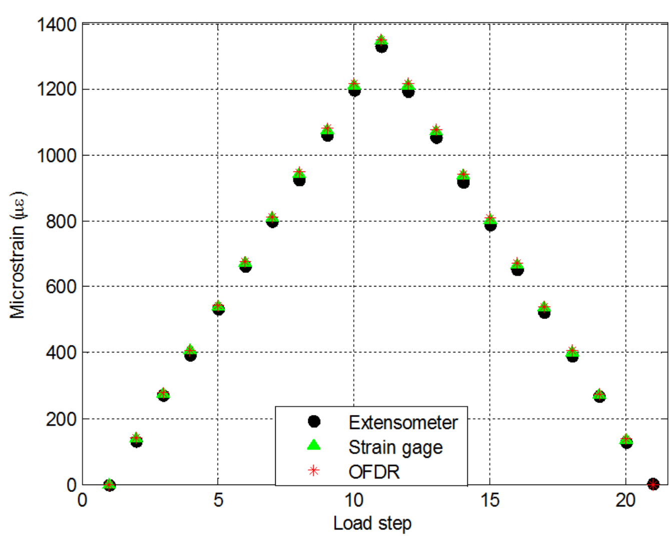
Strain Gages Configured Through Software

The HD-FOS sensor is constructed using standard fiber optic cable and comes in lengths from 1 meter to 20 meters (50 meters for ODiSI-A).[3] The sensor is bonded to a structures surface in a similar fashion to traditional strain gages and is flexible enough to be routed in a serpentine pattern.[4] In some cases the fiber can be embedded within structures, particularly when composites are used. **The fiber sensor comprises a series of densely spaced virtual strain gages, whose gage length and location are defined by the software in the ODiSI interrogator.** The sensor can be configured to provide strain measurements every millimeter along the fiber. As the test progresses, gage lengths and locations can be changed through software without physically changing the location of the fiber sensor.



Measurement Accuracy

Strain measurements taken using HD-FOS are as accurate as traditional strain gages. The data below compares strain measurements taken with HD-FOS sensors, foil gages and an extensometer as a coupon is tested to 1400 micro strain. The load is increased in ten equal load steps and then decreased to zero, retracing the same steps. As the data below shows, the deviation from strain gage measurements is 0.12% and the data tracks consistently through the range of load increments.



Sensor	Deviation from Foil Gage Reading
Fiber	0.12 %

Sensor	Deviation from Extensometer Reading
Fiber	1.14%
Foil Gage	1.26%

testforce

Sensor Installation

Mounting of the fiber strain sensor is very similar to the mounting of electrical foil strain gages. The same material is used and many of the steps are the same.

Surface preparation:

As with foil strain gages the first step is surface preparation. The exact process will vary by application, adhesive used and substrate material. For most applications some abrasion of the surface will be required to provide bonding zones for the adhesive. In a typical application the surface is sanded in a cross hatch pattern and alcohol is used to remove the residue. The surface should be completely dry prior to bonding the fiber sensor.

Routing the fiber sensor:

The next step is to route the fiber. Fiber can be routed in straight lines or in a serpentine pattern to provide a full field view of strain. As the fiber is routed along the test article, it can be held in position with some temporary means that leaves no film or residue. In the image below, small Kapton tape circles are used. The fiber should be pulled taut between Kapton circles so it is flush against the surface of the object.

Fiber bonding:

The final step is to apply adhesive to the fiber. For short term installations a cyanoacrylate based adhesive can be used and the adhesive applied with either a brush or cotton swab. For long term tests, high strain applications or installations in harsh environments, two part epoxies may be required. The ideal installation has an extremely small amount of adhesive between the fiber and substrate. Very fine paint brushes or squeegees can both work for this application.

Determining Gage Location

As with strain gages, when the fiber sensor is routed along the test article, it should be done in a defined pattern with a known relation to the physical dimensions of the test article. The ODiSI interrogator will interpret a specific gage location as a function of the distance from the beginning of the installed sensor. Before starting the test, it is important to identify the start point of the desired sensing region relative to a known point on the test article. This can be done in a number of ways.

Defining sensing locations on the fiber:

The location of the desired start point may be defined by entering into the ODiSI's configuration software it's exact distance along the length of the sensor. Any point may be defined in this way as well as segments between points or groups of points. This method of identifying gage location requires more specific knowledge of sensor position in relation to the test article.

Touch to locate function:

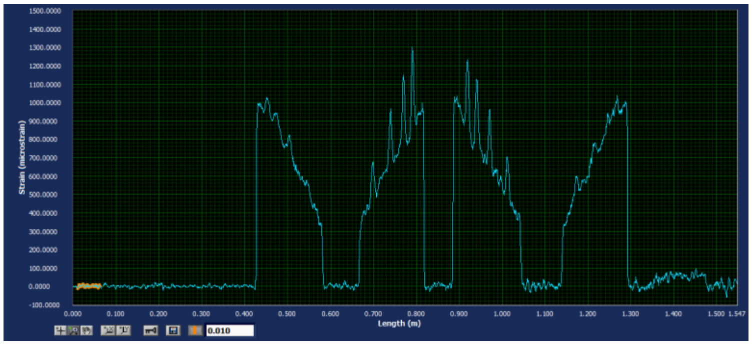
A more convenient method is to use the ODiSI's 'touch to locate' function. With this feature, a point at any location along the sensor may be identified by touching the fiber with either a hot or cold touch. This stimulus is registered by the sensor and it's exact location identified by the configuration software. The point can then be added to the test configuration. Several points can be added to define segments between points or groups of points.

Touch to locate screen

testforce

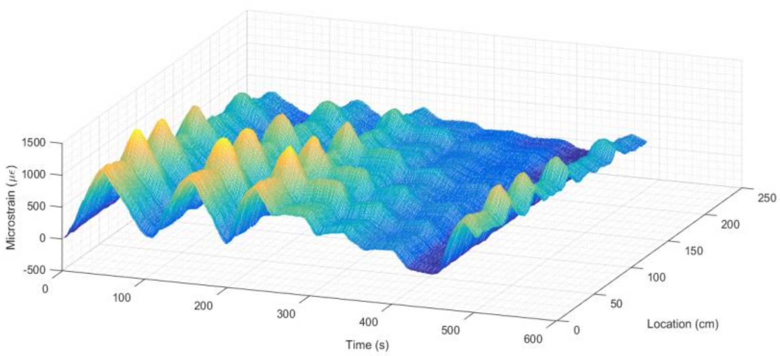
Data Collection, Presentation and Analysis

Strain Measurements Plotted vs. Length of Fiber Sensor



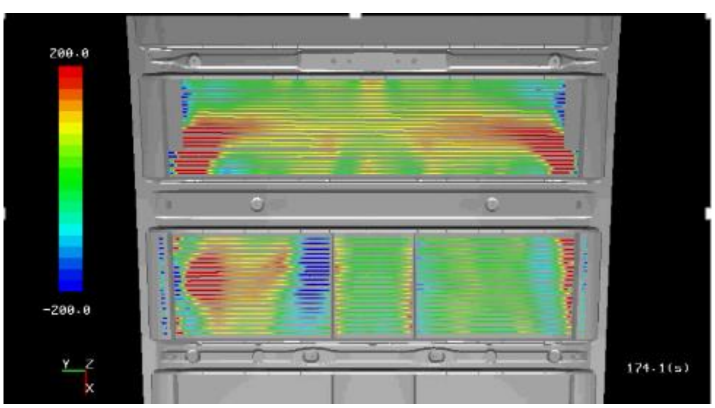
The strain gages can be defined and data displayed using a PC tool. Strain data can be displayed versus the length of fiber or select points can be displayed as a function of time. The PC tool can be used to redefine the strain gage length, the number of data points acquired and the position along the fiber sensor. Data can be acquired over the full length of fiber or from select segments.

High Definition Strain Data Exported to Matlab for Analysis



High definition strain data can be stored in a tab delimited text file for exporting to MS Excel or other 3rd party analysis software such as Matlab. The high definition data is sufficiently dense to provide a fully contoured view of the strain profile of a structure under load.

High Definition Strain Data Integrated with CAD 3D Model



The high definition strain data can be mapped to a 3D CAD model using Luna's 3D visualization tool. Using this tool, engineers can record data during structural testing and then replay the data superimposed on a CAD model of the structure under test. The 3D visualization tool is ideal for problem solving as well as creating presentation materials for management design reviews.

Conclusion

Luna's ODiSI, with high definition fiber optic sensing for strain, will save time and money for body in white structural testing. In most cases, a combination of strain gages and fiber are used to instrument a test article; with the end result being a significant reduction in instrumentation time and a far more detailed and illustrative data set.

The densely spaced data means engineers can see actual strain gradients across joints and structural members (vs. interpolating between broadly spaced point measurements of strain) thus arriving at the optimal design solution in less time.

Because the strain gage length and location are defined virtually through the ODiSI software, engineers have the flexibility to dynamically re-configure the test for closer examination of areas of interest. This virtual gage capability takes the uncertainty out of determining the best location for traditional point sensing strain gages.

The 3D visualization tool, connecting the acquisition of test data to the CAD infrastructure, brings test data to life and allows engineers to bring their problem solving intuition fully to bear. The images and videos created with the visualization software are ideal for design reviews and presentations

References

1. Development of Smart Design Process for Light Weight Body in White, SAE International 2015-01-1365, published 04/14/2015 – Shohei Matsuyama, Hiroyuki Yamashita.
2. Distributed Optical Sensing in Composite Laminate Adhesive Bonds, AIAA SciTech, 4-8 January 2016 San Diego California – Leeanna Meadows, Rani Sullivan, Keith Vehorn
3. Luna Innovations - FAQ Document
4. Luna Innovations – ODiSI Sensor Installation Quick Start Guide

Headquarters: 3155 State Street
Blacksburg, VA 24060

Main Phone: 1.540.961.5190
Toll-Free Support: 1.866.586.2682
Fax: 1.540.961.5191
Email: solutions@lunainc.com
Website: www.lunainc.com

testforce

Testforce Systems Inc.

Phone: +1-888-880-6804
Email: sales@testforce.com
www.testforce.com