New

Biosirus

Opto-Sensor

Strain Application Notes – Large Marine Vessels

(For details refer to the Opto-Sensor Temp & Strain Mapping System Brochure)

Most marine vessels are designed using sophisticated software and such designs are mostly validated through software simulations as well. Real-time monitoring of structural integrity of large marine vessels is gaining importance due to higher tonnage, taller structures, longer lengths, longer voyages and adverse weather conditions at sea (climate change). Large vessels (commercial/defence) are being increasingly deployed due to better designs and propulsion systems that allow longer stays at sea with an ability to navigate in most sea-state levels. Digitalization and high bandwidth satellite connectivity is leading to a growth in remote monitoring of these assets. *However, very few structural deflections are measured due to their measurement complexity and high cost. Recently, hull-cracks due to material corrosion, fatigue and sea-state stresses has been identified as one of the risks (requiring several months in hot-works repair). Today, structural integrity is assessed visually with sample plates cut from the suspected hull areas and sent to a laboratory for metallurgical examination and load tests (often requiring additional samples).* The new Opto-Sensor changes all this with optic fibers sensors providing real-time deflection (ΔL/L) measurements enabling a 3D digital strain-map of the key areas of the whole vessel (hull, compartments, engine room, superstructures) during its voyage.

General Overview:
Opto-Sensor is a two-part system consisting of (a) 19-inch rack mount unit and (b) optical fiber loops. Each unit can have up to 4 channels of dedicated fiber-loops where a single laser switches between each channel. A fiber loop can be dedicated to a test configuration, while other fiber-loops can be placed in-situ into the infrastructure permanently. Hence, a single Opto-Sensor unit can be used across multiple (or concurrent) measurements. The choice of the single-strand fiber and its jacketing (PVC, metal, etc.) is based on the application/mechanical requirement. The simplest fiber type is only hair-width. Also, a single channel fiber can be spliced into "zones" and terminated as a single loop. In multi-channel applications with high sampling rates (max 2 samples/minute) and long fiber lengths (in kms), a software adjustment is made to time-synchronize the various channel data-sets. *Both temperature and strain measurements can be done on the same fiber, but is not recommended.*

Creating a Strain Profile:
In strain/deflection applications (laboratory, real-time monitoring or digital twinning), the fiber needs to be "firmly affixed" (epoxied) to the object which is being measured. In simple applications, it could be a single fiber-loop running the entire length for all measurements (hull, compartments, decks, superstructure, etc.). For larger complex systems, a multi-channel system is best, where each channel can be segregated for different areas (engine-room, bridge, superstructure, hull, compartments, decks, etc.) based on desired focus. *Voyage parameters such as route, sea-states, speed, weather, payload and ballast-load all help corroborate strain measurements over time.*

Hull, Compartments & Decks: As a focus area, each level will need to have sensor matrices (both vertical & horizontal) epoxied to the walls of the hull, ballast tanks and deck floors, terminating to a floor-hub. These floor hubs will connect in series with others as a single channel in the main unit. For some vessels (and submarines), multiple independent routes may be required. Measurements around the waterline allow recording impact of sea-state (thrashing waves) on the hull.

Engine Room/Bridge/Superstructure: It will be prudent to have some coverage of the bridge and superstructure both vertically (longitudinal flex) and across it (transverse flex). This is especially important for taller and wider superstructures. The fiber cannot measure machine vibrations, but can record floor/wall deflections in engine room.

Corrosion: Notwithstanding cathodic protection and coatings, saltwater accelerates hull steel corrosion. This corrosion promotes surface cracking in hull walls. The strain measurement would capture this weakening trend over time (increased deflections) and help identify areas that require steel replacements during maintenance (shipyard hot-works).

Strain Measurement:
The fiber needs to be run in a continuous path for each segment/zone terminating on a channel in the 19-inch rack unit. It is advisable to use separate channels for each critical area. *The fiber needs to be epoxied along its entire route for accurate measurement.* The fiber bend radius depends on the fiber selected and can be as small as few cm. The fibers can

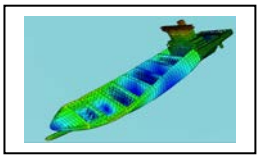
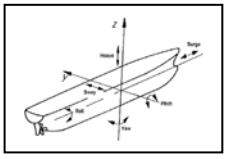
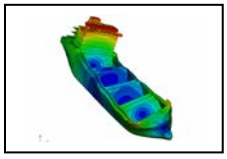
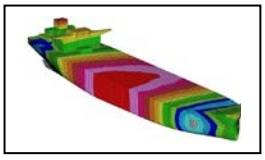
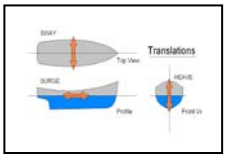
be placed close to each other and there is no risk of any "coupling effect" or electrical interference. It can detect elongation/sags/flexes and pin-point such locations. If the fibers are to cross, care must be taken that one does not "pinch" the other and affect the laser light path.

Temperature Measurement:
While both the temperature and strain measurements can be done together on the same fiber, the fiber orientation for strain measurement may force using its own dedicated fiber (separate from the temperature fiber). Also, while the strain measurement requires the fiber to be epoxied, the temperature measurement may require mere proximity. *A separate channel should be used for temperature measurements (rooms, cable raceways, engine-room, flue and other areas).*

Other Notes:
The 19-in rack unit is independent of the fiber applications. It is a moveable asset to be used across multiple locations/experiments (laboratories, various experiments and/or digital twinning applications). *It is however recommended that each marine vessel has its own dedicated system to be able to gather real-time data all year-round. Such data could be fed into a SCADA for alarms.* The fiber can be procured locally and is the only consumable. Its selection (jacket type) for low impact can be inexpensive. The copious data at a sampling rate of every 1-15 minutes, every 1 meter along the fiber, can be stored in the unit or transmitted to a cloud or SCADA/HMI systems. The max fiber loop length per channel is 20 km. (longer lengths can be explored). Pre-engineering services to obtain optimum fiber layout and positioning for a given project is available. *The best part is that only a few fiber connections are needed even for the most complex measurement. It easily substitutes hundreds (if not thousands) of strain sensors and thermocouples.*

A. Laboratory Applications:
Such tests include measuring strain profiles on steel plates (new & degraded) of varying thickness. Often these tests are conducted indoors or on a larger sample outdoors (in shipyards) to confirm simulation results.

B. Calibration and Periodic Verification across Fleet Class:
Should a real-time system not be required for each vessel, the 19-rack can be deployed on those vessels pre-fitted with the fibers (in each fleet class) to periodically verify operational strain profiles on a voyage against a standard profile developed for the class. Such recordings will be akin to sample results.

C. Digital Twinning Applications:
In digital twinning applications the entire vessel is profiled in real operating conditions. Such measurements include strain profiles associated with varying speeds, sea-states, storm surges/high waves and other parameters. This digital profile is then either used stand-alone for simulation (and training) to understand operating limits and/or stored onboard in the SCADA to help predict and manage real-time operating limits as they arise.

D. Real-time Monitoring & Performance Applications:
It is recommended that large (or high value) vessels be deployed with its own real-time system. This would allow for real-time measurements into SCADA for alarms and corrective actions. Principally, the performance optimization would include early detection of (a) localized area hull cracks; (b) hull weakening; (c) residual life; (d) a more focused and much shorter dock maintenance; and (e) avoid forced outages at sea.

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