Case Study

Early warning system for structural failure

Structural monitoring trial shows excellent results

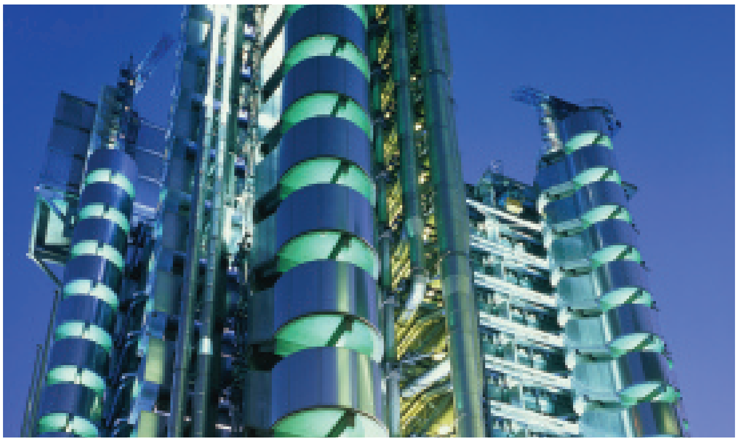
A reliable method of measuring strain and predicting the impending failure of steel structures has been demonstrated by the successful trials of Sensornet's distributed temperature and strain sensor (DTSS).

In a BP laboratory trial that is believed to have been the first direct measurement of compressional strain in an optical fibre using Brillouin scattering, the Sensornet DTSS system proved its ability to detect the yield point of a steel tube subjected to loads – and to pinpoint which sections were under the highest strain once that yield point had been passed.

ANATOMY OF THE TEST

To simulate a range of operating conditions, a 15.5ft length of 7″ tubing (known in the industry as casing) was installed in a 40-million pound load frame. Bare fibre and fibre cable, attached to the external faces of the casing using a number of different methods, acted as the sensor.

The DTSS system – was configured to give a 1°C temperature resolution and a 20με strain resolution for a spatial resolution of 1m. The system is housed in a rugged field-transportable 19″ rack-mountable box with inbuilt PC, which includes a network connection, flip-up monitor, keyboard and uninterruptible power supply.



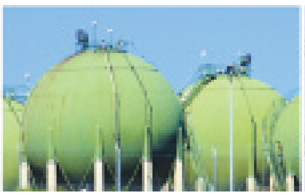
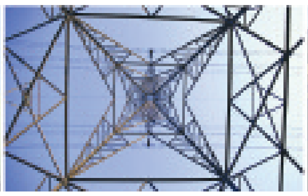

The striking steel structures of Lloyds Building in London and the Pompidou Centre in Paris

The Sensornet DTSS system proved its ability to detect the yield point of the tubing – and to pinpoint which sections were under the highest strain once that yield point had been passed.

As a result, Sensornet is now developing a production DTSS system capable of the long-range monitoring of structural elements. The development will also deliver the necessary fibre optic cabling, installation techniques and data interpretation software.

A unique feature of the Sensornet DTSS is its ability to measure strain and temperature independently by analysing the full Brillouin spectrum, eliminating the usual cross-sensitivity to temperature.

Fibres were attached to the outside of the tubing in a series of runs along the top, sides and bottom.

Data were acquired while the casing was subjected to a variety of tensional, compressional and bending strains at temperatures ranging from ambient (around 20°C) to elevated (between 114°C and 137°C). The Sensornet DTSS collected two raw data sets: Brillouin spectra data providing 3D contour maps of the anti-Stokes and Stokes lines, and optical time domain reflectometer (OTDR) loss data.

Both sets of data were processed to determine the temperature and strain along the tube. The Sensornet DTSS was able to isolate compressional and tensional strain and so was able to simultaneously determine the direction and amount of bending along with any additional compression or tension applied to the tube. Bending and tension measurements were also taken at elevated temperatures during a test designed to pull the casing to its failure point.

RELIABLE RESULTS

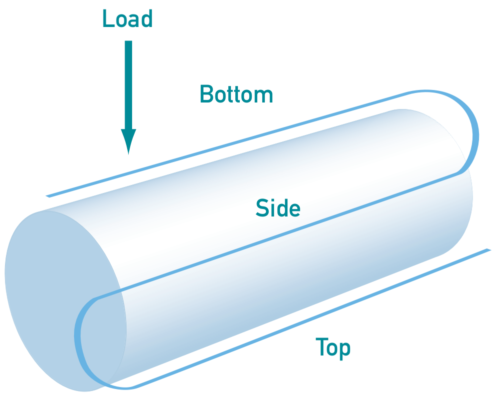
The tests proved the ability of the Sensornet DTSS to take reliable distributed measurements of temperature and strain. The system's accuracy was checked against results from ten point strain gauges that were also fitted to the casing to provide a reference – and found to be excellent. However, by taking distributed rather than point measurements, the DTSS provided strain field information that would otherwise have been unobtainable. In particular, the DTSS identified when the yield point was reached, and accurately pinpointed the location of the resultant "necking" – information that was missed by the conventional point sensors. The DTSS continued to measure accurate strains up to the point where the chuck holding the casing failed (2.6% strain).

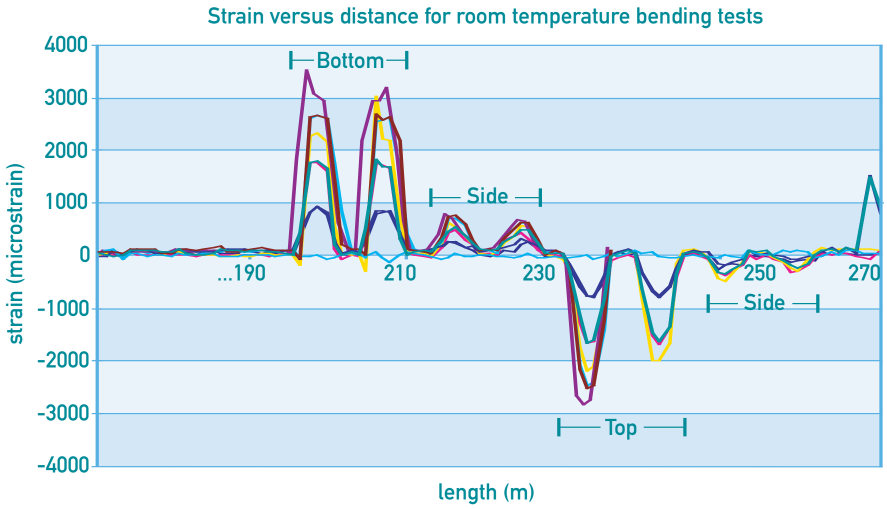
The tests confirmed the potential role that the Sensornet DTSS system could play in predicting potential failures in structures, thus enabling preventive action to be taken.

BRILLOUIN SCATTERING

The phenomenon of Brillouin scattering was discovered by the French physicist, Léon Brillouin (1889-1969), and its measurement is at the heart of the Sensornet DTSS system. Brillouin scattering is a type of reflection that occurs when light is shone into an optical fibre. An optical fibre guides not just light waves, but also naturally occurring sound waves. An interaction between the light waves and sound waves travelling within the fibre causes Brillouin reflections. Brillouin reflections comprise two components – Stokes and anti-Stokes light, each being a different colour from the original light in the fibre. Brillouin reflections are very sensitive to changes in the fibre arising from external effects such as temperature, strain and pressure.

Demonstration of Sensornet's DTSS system detecting strain in structural member





RESULTS: The DTSS measured the full distribution of tensional, compressional and bending strains with a 1m spatial resolution. The DTSS detected the elastic limit of the casing, the onset and exact location of necking and continued to measure at very high strains, where point gauges had failed. The test was a complete success.