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A revolution in structural monitoring

ASC's accelerometers improve bridge safety

Bridges are exposed to immense loads. Their operational safety must therefore be regularly monitored. Continuous condition monitoring of structures has now established itself as an alternative to costly on-site inspections. Dewesoft's high-performance data acquisition systems and ASC GmbH's high-precision inertial sensors are already being employed on many bridges, including the colossal Hong Kong - Zhuhai - Macau Bridge in China.

In October 2018, the world's longest sea bridge was opened to traffic. The structure spans the estuary of the Pearl River, significantly reducing travel times between the three cities. However, as the bridge is located in an area of heavy shipping traffic, extensive precautions had to be taken in the event of a collision. A dense structural health monitoring network therefore ensures that if a watercraft collides with one of the concrete piers, the bridge operator's control center immediately receives detailed information about the damage so that appropriate action may be taken.

ASC's high-precision accelerometers and Dewesoft's powerful data acquisition system play a central role in the safety concept. Together, they provide a comprehensive bridge condition monitoring solution that is optimally adapted to the structure.

A complete package that won over the bridge operator

Both measuring technology companies were awarded the bridge instrumentation contract one year prior to completion of the structure. A common Chinese sales partner put ASC and Dewesoft in contact with each other at the time and they quickly decided that the two companies should work together. "Our analog inertial sensors have a compact and robust design and are very easy to operate using Dewesoft's data acquisition systems," explains Markus Nowack, Application Engineer at ASC.

The Chinese bridge operator chose the ASC CS-1611LN triaxial capacitive accelerometers because they offered the best price-performance ratio. The operator of the Hong Kong - Zhuhai - Macau Bridge installed 44 ASC sensors laterally in the heads of the bridge piers, where they detect even the smallest deviations from the typical vibration frequency for the material being monitored. The data collected is then evaluated by the data acquisition systems.

Capacitive accelerometers with current output signal offer ideal operating conditions

From the very outset, the Hong Kong - Zhuhai - Macau Bridge was a mammoth task for a first joint project. Indeed, the signals from the sensors installed on the bridge piers must be transmitted

ASC GmbH | Ledererstraße 10 | 85276 Pfaffenhofen / Germany
Tel.: +49 (0) 84 41 / 78 65 47-0 | Fax: +49 (0) 84 41 / 78 65 47-9 | office@asc-sensors.de | www.asc-sensors.de
Geschäftsführung: Renate Bay | Amtsgericht Ingolstadt | HRB 4084 | Ust-IdNr. DE247900685

loss-free over very long distances. ASC's CS-1611LN triaxial accelerometers always ensure that this is the case thanks to their current output signal of 4-20 mA.

Typical natural frequencies of structures and their components often lie within a low frequency range, below 10 Hz. Highest precision and reproducibility of the measurement data are the basic requirements for a reliable structural health monitoring system, in particular when it comes to the long-term monitoring of vibrations of very small amplitudes in this lower frequency range. Accelerometers based on capacitive technology are therefore an excellent choice for analyzing the bridge's structural integrity as well as for the detection of calendrical or cyclic influences, overloads or material defects.

Furthermore, sea bridges are subjected to a wide variety of loads. Capacitive accelerometers are also optimal for detecting low-frequency aerodynamic fluctuations, wave-induced influences, hydrodynamic forces, and seismic movements of the seabed. This technology can measure static (DC) and constant accelerations, thus reliably detecting component velocity and displacement.

The ASC CS series is therefore ideal for use in structural health monitoring (SHM), as these accelerometers feature very low broadband noise (<0.2 µA) within the frequency range employed (<100 Hz) and excellent long-term stability. They are also available in uniaxial, biaxial, and triaxial versions. The sensors also feature an integrated cable whose length is customizable.

Effective analysis thanks to powerful data acquisition

"The accelerometers operate at a data rate of 100 Hz, so they transmit 100 measurement points per sensor and per second," says Nowack. A powerful data acquisition system is required to synchronize and assess the signals from these sensors, along with those of many others. This is where Dewesoft, a leading manufacturer of these systems, comes in. Dewesoft manufactures state-of-the-art testing devices and measurement equipment that can be found in renowned laboratories worldwide. The data acquisition systems can synchronize data from numerous different channels and offer many adjustment possibilities. Dewesoft X3 records, analyzes and visualizes the data. The software is easy to use and boasts a wide range of functions.

Even real-time evaluation is possible

Dewesoft's SIRIUSie-8xLV data acquisition system evaluates the measurement signals of the Hong Kong - Zhuhai - Macau Bridge. This system is equipped with an EtherCAT® FO converter, whose low latency design makes it possible to transmit data over distances of several kilometers. The SIRIUSie-8xLV has amplifiers that can acquire data from almost any commercially available sensor. It synchronizes the channels with sub-microsecond precision, allowing the user to perform an in-depth structural analysis of the data. Another advantage of the system is the integrated

OPC-UA interface, which enables live data output and therefore also real-time data evaluation. Furthermore, the data can be exported in various formats.

Over 200 acceleration channels distributed over many kilometers are needed to monitor the Hong Kong section of the bridge alone. Dewesoft has bundled the channels into six independent subsystems which synchronize with each other with a latency of <1 ms. The data collected by the subsystems are stored both locally and on a central server.

A major need for structural health monitoring

The most notorious example in history dates back to 1940, when the first Tacoma Narrows Bridge (USA) collapsed only a few months after opening. Unfavorable aerodynamic conditions caused the bridge to resonate and eventually collapse due to torsional vibration. The most recent example is the Polcevera Viaduct (Morandi Bridge) in the Italian city of Genoa. The 1,182 m long structure partially collapsed in 2018. Condition monitoring of bridges using sensor technology will no doubt gain in popularity over the coming years.

Another reason for this is also because there are so many aging infrastructures. In Germany alone, thousands of structures are in need of renovation. "However, replacing a structure takes time. In the meantime, the old bridge must remain safe to use for as long as possible," says Nowack. "Sensor-based structural health monitoring provides the perfect solution." By continuously recording the vibrations on a bridge, damage can be detected very early on. This means that run-down structures do not have to be prematurely closed as a precautionary measure, but can remain in operation until they are truly no longer safe to carry traffic.

Remote monitoring also offers two other major advantages. Firstly, costly on-site deployment of engineering teams can be greatly reduced. Secondly, the sensors monitor the bridge around the clock, whereas inspections by experts can only provide a snapshot of the structure's condition. That is why ASC’s sensors can be found collecting valuable data on a great number of bridges, not only in Asia, but also in France, Great Britain and Germany.

Smart sensors considerably simplify monitoring

ASC’s inertial sensors are also available in a smart version. These sensors independently analyze and evaluate the recorded data so that bridge operators can dispense with the task of externally post-processing it. This significantly reduces the expense involved in analysis and evaluation, since the integrated algorithms can be used to generate status reports at any time, using the traffic light principle, for example. The sensors can also forecast damage development, which means that maintenance requirements can be identified at an early stage and appropriate measures can be planned effectively.

Smart sensors can also be used to create virtual bridge models. These digital twins can then be used to simulate the effects of a wide range of environmental conditions on the structure, based on sensor data from the real bridge. Divergences between actual and expected system behavior can be quickly detected by combining measurements and simulations. The digital twin can be used throughout the structure's entire life cycle and to optimally adapt bridges to the topographical and meteorological conditions at their future location, as early on as the planning stage.

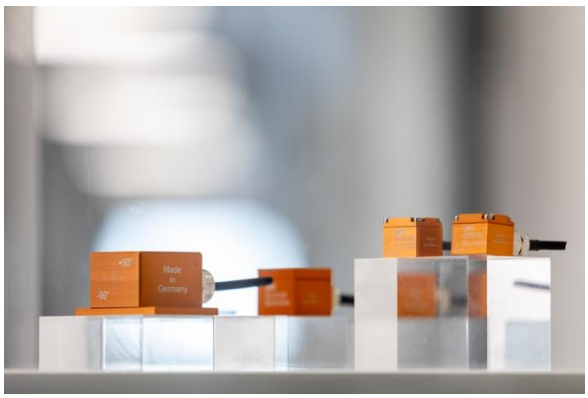
Images

ASC and Dewesoft have equipped the world's longest sea bridge with a high-precision monitoring system

Image: tmlau/shutterstock.com/Montage: K+P

The ASC CS-1611LN triaxial capacitive accelerometer detects even the slightest vibrations on the bridge

Image: ASC GmbH



ASC offers a wide range of accelerometers, gyroscopes and tilt sensors, as well as Inertial Measurement Units

Image: ASC GmbH

Dewesoft's powerful SIRIUSie-8xLV data acquisition system can synchronize data from many different sensors

Image: Dewesoft

Keywords: Bridge monitoring, structural health monitoring, data acquisition, SHM, Hong Kong - Zhuhai - Macau Bridge, accelerometers, sensor technology, smart sensors, intelligent sensors, Dewesoft, ASC GmbH

Title: ASC sensors make bridges safer

Meta-Description: Capacitive accelerometers detect even the slightest changes in structures, making it possible to react early on. More information

Links: https://www.asc-sensors.de/en/applications/construction/
https://dewesoft.com/case-studies/distributed-monitoring-on-world-longest-hong-kong-zhuhai-macao-bridge