“Light Flight” New Technologies for dynamic strain measurement sensors

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Strain measurements are really demanding to new autonomous and intelligent materials affordability and new technologies are under development. In this article there is a brief summary of a series of tests have been carried out at C.I.R.A. laboratories in Italy comparing new fiber optic sensor system with strain gauge (for static) and piezoelectric sensor (for dynamic).

Those sensors can have many different applications: in aeronautic field all kind of strain tests are very common and the challenge of “On-Line” Structural Health Monitoring systems is to identify suitable technology, able to standardize the use of fiber optic sensors, during the life of aeronautical components. These ones work usually under high mechanical and thermal stress. In particular, airplanes suffer high mechanical stress during take off and landing, principally on the wings and landing gears or, for space applications (satellites or spacecraft), they suffer also significant thermal loads.

Two type of tests have been conducted at CIRA Laboratories : static and dynamic , by using following sensing technologies: FBG Fiber Bragg Gratings, strain gauge sensors for static test and calibration (COTS item available on the market) and dynamic piezoelectric sensor, a new technology by PCB Piezotronics used in this work for dynamic calibration and test.

FBG’s used in this work have a gage length of 1 mm. They are obtained by modifying the core of an optic fiber by a masked UV beam. Nowadays they are COTS components. FBG sensors act as a filter for a particular wavelength $\lambda_{B,}$; in particular, in this work, the FBG used have a wavelength of 1550 nm. FBG can be used in transmission or in reflection mode. In the first case, one fiber end is illuminated with a laser source and, at the other end, the filtered light can be observed (i.e. by a spectrum analyzer).

The measurement system for FBG sensors is an original device developed by CIRA which output is a signal Vo proportional to strain acting on optic fiber: therefore it must be conditioned with a commercial A/D acquisition Sw/Hw. For the static test three type of loads were applied during the tests: W = 7,9 g ; W = 50 g ; W = 1015,2 g. The results obtained with these loads shown a perfect overlapping between strain gauge and FBG. During these static tests, a good sensitivity of FBG sensors was experimented with respect to the different loads, so that they can be used to substitute strain gauges; also high measure repeatability was observed.

In dynamic tests the FBG has been compared with an ICP piezoelectric sensor (by PCB Piezotronics) performance. The two sensors have been both bonded using the same adhesive (cianoacrilate) on an aluminium cantilever beam as in the previous static tests, at the same distance with respect to the cantilever beam axes.

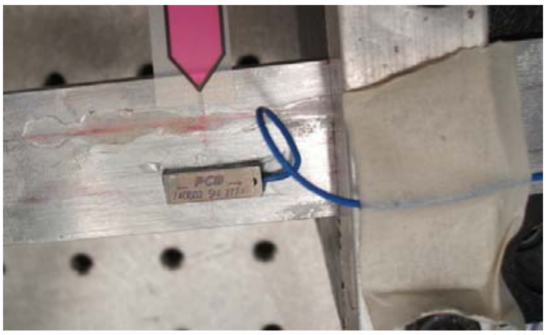

Fig. 1. Aluminium cantilever beam with FBG and ICP sensors

The instrumentation devices are described in fig. 2. One end of the cantilever beam has been fixed to a shaker connected to a function generator and a signal amplifier. The same signal coming from the amplifier was acquired by a multi-channel reader, connected to the ICP sensor. The reader was in turn connected to a A/D Converter and the FBG reader. The sensitivity of the reference dynamic sensor, PCB Piezotronics type 740B02, as reported in its datasheet, is 48,052mV/με for aluminium base of mounting. This quartz sensor has very unique features: is reusable, so very cost effective, and easy to mount with cianoacrilate, just like an accelerometer. And just like an accelerometer can be used with a direct connection with measurement system thanks to ICP ™ technology. Furthermore this type of sensor is available in several different versions offering wide frequency range (up to 100KHz depending on mounting base material) , high sensitivity , range (up to 1000 με) and resolution (around 0,6 nε).

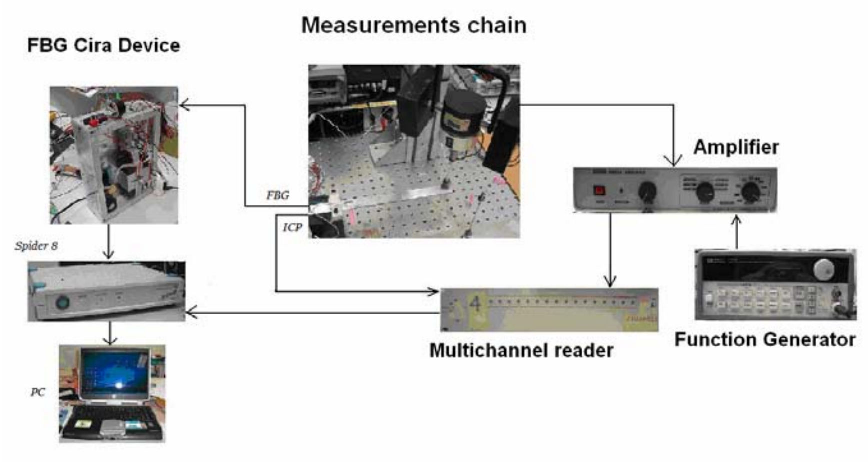

Fig. 2. Measurement System Block Diagram

The strain measured by FBG during dynamic tests was acquired. Dynamic tests have been performed at different frequencies; starting from 1 Hz to 200 Hz. fig. 3. The red line represents the FBG sensor signal, while the blue is the one coming from the PCB sensor.

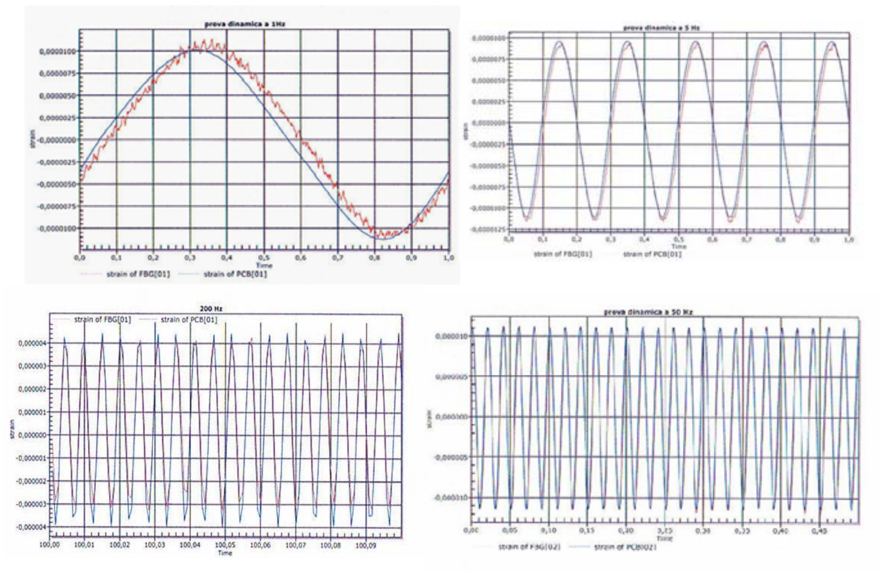

Fig. 3. Dynamic tests at 1 Hz, 5 Hz, 50 Hz and 200 Hz.

It is possible appreciate that the graphs show a delay (hundredth of seconds) from the reference sensor signal but at higher frequency (50, 200 Hz) the graphs are perfectly overlapped and the delay between the two sensors is reduced.

In conclusion, the preliminary dynamic tests, performed in this work, make evidence that FBG sensors for frequency up to 200 Hz; are affordable and may replace classical dynamic strain sensors.

Other studies are however necessary on this argument to use this new FBG sensors extensively, in dynamics.

In this work, a preliminary calibration of an optical fiber sensor has been carried out, to compare their sensitivity with respect to traditional sensors.

The result of this tests demonstrate the excellent performance of the reliable ICP type 740B02 by PCB Piezotronics as a suitable sensor for any dynamic strain sensor for test and monitoring. Also the new fiber optic sensor with original CIRA developed system offers good results for static test and monitoring .

In particular the results can be useful in the aim to monitor "on-line" the life of composites, during their period of life, allowing the safeguard of structural health and the safety of the machine (car, boats, airplane, satellite...) in particular manufactured with composite materials.