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Low-Cost Lock in Thermoelastic Stress Analysis

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Abstract

In this work, we introduce a low-cost Thermoelastic Stress Analysis (TSA) system for structural health monitoring. We show that the system is capable of generating TSA signal magnitude maps using a lock in reference signal provided by either RSG (resistance strain gauges) or FBG (Fibre Bragg Grating) point measurements.

Keywords — Thermoelastic Stress Analysis (TSA), low-cost

Introduction

A structural health monitoring system that is able to be integrated within an aircraft assembly is being developed. A prototype low-cost system that incorporates RSG and an infrared camera for TSA has been built and tested. It comprises of a Raspberry Pi 4, 16-bit analogue to digital converter (ADC), FLIR Lepton microbolometer and a 350Ω Wheatstone bridge (WSB) in a quarter bridge configuration; all available as commercial off the shelf components (COTS) at a cost under £250.

Method

Using time-stamped point measurements of strain obtained from the RSG as a reference loading signal, it is possible to lock-in the thermal images to produce thermoelastic data using a least mean square fitting method and subsequently generate full-field TSA maps that require minimal post-processing. Post-processing is performed on the Raspberry Pi and the output from the system is time-stamped RSG point measurement data and TSA maps. The sensor system can be operated independently or connected through a graphical user interface (GUI) so that data can be viewed in near real time, remotely from the sensor system.

As an alternative to taking the reference signal from the RSG point measurements, the technique has also been demonstrated to work using FBG measurements as the lock-in reference signal.

To test the system, aluminium alloy 2024-T3 test specimens (200x40x1.6mm) with a hole (6mm) in the centre, coated using aircraft primer paint were uniaxially loaded at 4.95kN±4.05kN at a constant cyclic frequency of 1Hz. Figure 1 shows a typical experimental setup and reference signal data acquired simultaneously from both RSG and FBG on a test conducted at EMPA.

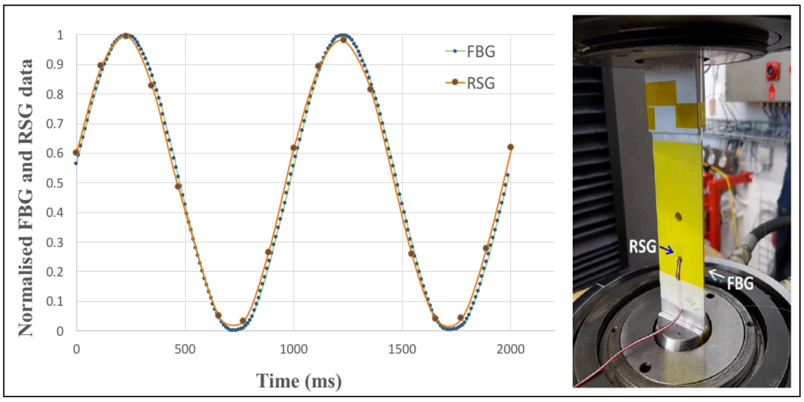

Figure 1 – left: Simultaneously acquired data from RSG and FBG used as reference lock in signals for TSA. right: Test specimen setup

Results

TSA results from a representative test can be seen in Figure 2.

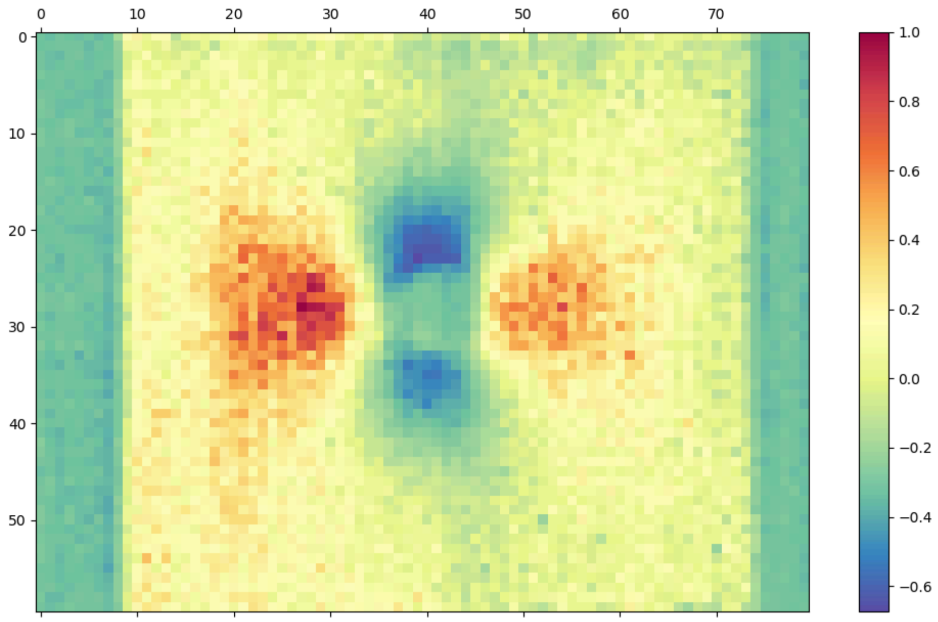

Figure 2 - Normalised TSA signal magnitude calculated from 256 RAW thermal images using RSG as the reference lock in signal

Conclusion

We have presented a novel low-cost system for performing TSA. The experimental results show that the system is capable of generating TSA magnitude maps from uniaxially loaded specimens at constant frequency. The targeted application for this system is on aircraft structures and will be further tested on a wing specimen at EMPA, on the LOV (Limit of Validity) wing test at Airbus, Filton and also on carbon fibre reinforced polymer (CFRP) fuselage throughout the course of 2020. This project has received funding from the Clean Sky 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 820951.