Real-time condition monitoring of an uncrewed aerial vehicle using a scattering-based specklemeter interrogator

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Growing numbers of uncrewed aerial vehicles (UAVs) in delivery, surveillance, and military applications are driving the need for automated flight inspections. Traditional inspections are done by ground maintenance crew, which limits total number of operational drones. Here we propose a condition monitoring solution combining optical fibre Bragg gratings (FBGs) with a newly developed scattering interrogation system. Our demonstration shows system stability and effective monitoring of strains incurred on the UAV wings during flight.

Although speckle pattern recognition has been used previously in spectrometers, instability-related errors has largely limited their application [1,2]. Recently, our group demonstrated a spectrometer based on a laser-written scattering chip inscribed inside a custom-made optical fibre with a rectangular cross-section. When input light was coupled into the fibre, the scattered light formed a stable speckle pattern that enabled reliable spectral reconstruction [3]. By applying principal component analysis (PCA) and relevant calibration procedure, the system can also interrogate shifts in fibre Bragg gratings [3]. For the purpose of on-board strain monitoring during the flight of a 2-meter wingspan drone, the scattering interrogation system was assembled into a compact battery-powered unit (Fig. 1 (b)). The FBGs were attached to both wings using epoxy resin, thereby allowing for in-flight monitoring of localized loads/strains. The collected data was compared with conventional fatigue indicators, namely an electronic accelerometer, located in the autopilot unit during five flights each lasting up to 15 min and streamed to the ground station at 10 Hz rate.

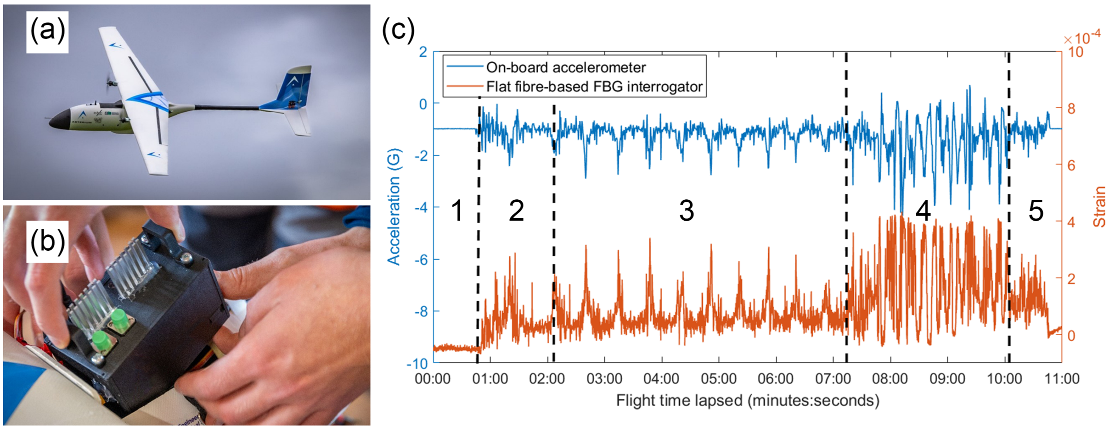

Fig. 1 Test of interrogator unit: (a) tested UAV drone plane in-flight, (b) mounting interrogator into the fuselage, (c) on-board accelerometer readings and wing strain sensed by FBG interrogator. Note: dashed lines indicate flight phases: (1) idle drone at the runway, (2) take-off and climbing altitude, (3) autonomous orbiting, (4) manual aerobatics, (5) descent and landing.

The clear correlation of two data sets confirms the successful operation of the demonstrated scattering interrogator (Fig. 1 (c)). Flight tests not only verified continuous operation of the interrogation system and its ability of in-situ (10 Hz) monitoring of strain values, but also confirmed correlation between the normal acceleration measured with the aircraft accelerometer and the wing strain changes. During UAV take-off, the interrogator recorded strain fluctuations from 0 to $300\mu\varepsilon$. While orbiting, periodic strain variations were observed, correlating with wind direction. Aerobatic manoeuvres revealed sharp strain changes, with peak values reaching $400\mu\varepsilon$.

To our knowledge, this is the first demonstration of a scattering-based FBG interrogator with high environmental stability, including operation under aerobatic flight conditions. This compact and lightweight system has future application potential including on-board continuous structural monitoring of UAVs.

References

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