Recent progress on fibre optic shape sensing for aerodynamic applications

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Extended Abstract

Shape conveys information about a structure that is easily visualized and interpreted, and its measurement (Floris et al. 2021) has applications across medicine, robotics, aerospace and civil engineering. The capability for shape measurements could be a key enabling technique for future advances, for example shape morphing aerospace structures. The shape of an object may be deduced *indirectly* from strain measurements made at strategic locations, processed using strain-deformation retrieval methods. This approach has been explored widely in recent years, including in aerospace applications by organizations such as NASA, often using optical fibres as the strain sensing technology. Optical fibres offer a number of advantages compared to standard strain gauges, notably their flexibility, low weight and small dimensions (~0.1 mm diameter). In addition, optical fibres can be embedded within fibre reinforced composites during fabrication, or can be surface-mounted to facilitate retrofitting.

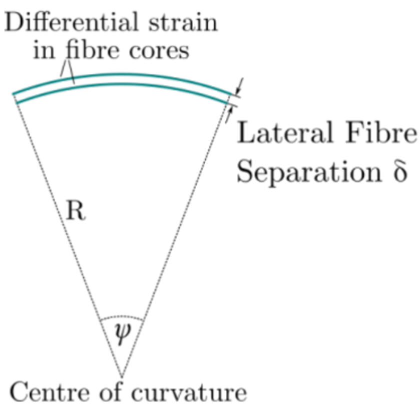

Fig. 1: DFOSS principle using differential strain measurements of local curvature to obtain shape through integration.

In contrast to indirect shape sensing techniques, direct fibre optic shape sensing (DFOSS), has the ability to measure shape directly using an optical fibre/fibre arrangement, allowing the fibre curvature, and therefore the path along a structure to which the fibre/fibre arrangement is attached, to be followed through space in three dimensions using simple path integration (see Fig. 1). A major advantage of DFOSS is that it removes the requirement for a detailed structural model of the underlying structure. Since shape is determined directly from within the sensing fibre/fibre arrangement, there is no reliance on external strain transfer from the structure and even simple surface mounting can be sufficient, providing interesting new experimental opportunities.

Recently introduced DFOSS techniques have been successful in improving the achievable measurement resolution and in making the technology more robust. In particular, DFOSS using fibre segment interferometry (Kissinger et al. 2018) offers dynamic (>kHz) shape change data with resolutions in the micrometre range. This allows in-situ measurements of aerodynamically-introduced structural deformations directly on aerodynamic structures, for example on helicopter blades. This has been demonstrated in several experimental campaigns, including for shape measurement on static helicopter blades (Weber et al. 2021), evaluating mode

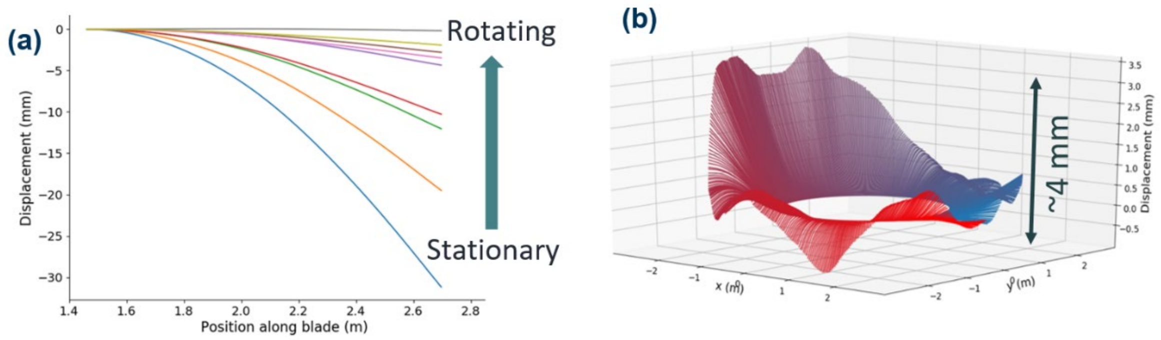

Fig. 2: Example measurement data from a helicopter trial, where (a) shows the rising of the blade during start-up, while (b) plots a vertical shape change over one helicopter rotation period.

shapes and modal frequencies, and as part of trials (James et al. 2022, Kissinger et al. 2022) on a rotating helicopter (see Fig. 2).

This contribution will report on recent progress and developments of this still relatively new technological approach.

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