Fibre optic sensors can detect flow events and flow speed via cross correlation of bending signal

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Abstract: Using Cross-Correlation (CC) of the Time Difference Of Arrival (TDOA) to determine the flow speed of arriving flow structures using the bending of FBG sensors, demonstrating FBG sensors capability for source localization applications.

Keywords: Cross-correlation, Sensor design, Bare FBG

1. Introduction

This study investigates the feasibility of replacing existing whisker–like sensors such as visually tracked, plastic fibres[1], or MEMS based sensors[2], with sensitive FBG / backlight scattering based fibres for flow monitoring and source localization applications. Visually tracking plastic fibres is difficult in many applications as this requires line of sight to the sensors and is sensitive to camera movement or loss of focus for longer term applications. These are some of the advantages of FBG based sensors, which can operate over long time periods, and without visual feedback.

The bending forces for a cantilever beam are concentrated at the root, and so a grating at the root of the fibre is the best way to capture the bending motion. Coated fibres are more resilient to forces or impacts when deployed, but would be more sensitive to unwanted temperature changes[3]. With the wide temperature operating range of glass fibres, a temperature adjustment using gratings not under load must be used to compensate for any heating or cooling as a result of the flow. A temperature adjustment grating, on a different light wavelength to the root bending grating, is positioned at the tip of the fibre where bending is minimal, and the signal recorded by the root grating can be adjusted by some factor of the temperature grating depending on the arrangement.

The temperature adjusted output of two or more sensors of known position can be cross-correlated to calculate time delays between sensors. In this study, two sensors in one dimension monitor the travel speed of a flow disturbance. A similar 2 sensor setup could be used to calculate the convection speed of a disturbance in an established flow. Multi sensor arrangements could be used to monitor both disturbances and convected flow patterns in 2D and 3D flow environments using TDOA based multilateration or other adapted localization techniques[4].

When deployed, the fibre should be shrouded in a casing suited to the expected forces of the flow, with a suitable diameter and Young's modulus that allows the fibre to bend, while being strong enough to stop the delicate fibre breaking.

2. Conclusions

This study has demonstrated that glass FBG sensors can be both strong enough to withstand experimental loads, and sensitive enough to capture gusts or even flow structures in established flows. When coupled with CC and TDOA based multilateration for source localisation, this will further the development of more versatile, temperature corrected, optical fibre flow sensors.

3. Figures and tables

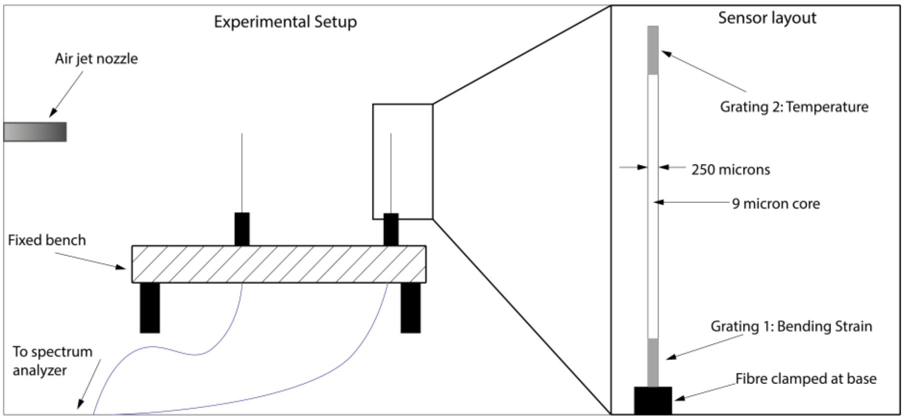

Figure 1 The fibre mounts could be moved between positions in a slot on the bench to vary the distance between the sensors

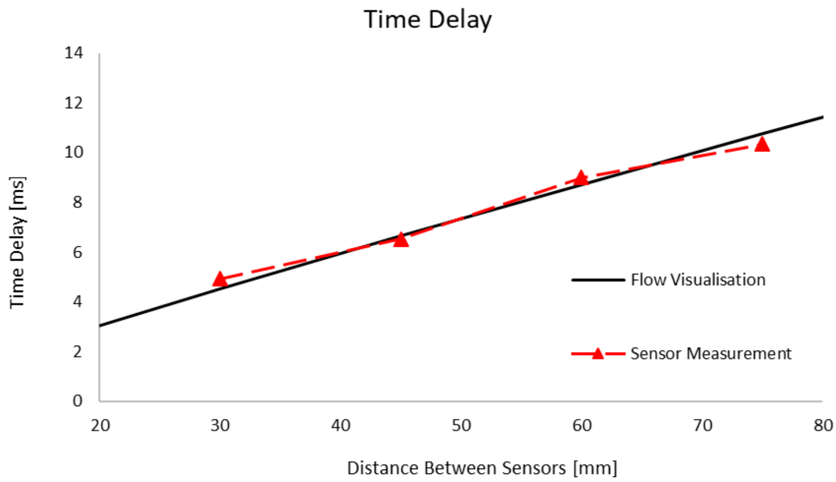

Figure 2 The front of a jet of air was tracked using schlieren imaging and a high-speed camera (1000fps) recording the nozzle exit.

Acknowledgments

The position of Professor Christoph Bruecker is co-funded by BAE SYSTEMS and the Royal Academy of Engineering (Research Chair No. RCSRF1617\4\11), which is gratefully acknowledged.

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