Strain Transfer Estimation for Complex Surface-Bonded Optical Fibres in Distributed Sensing Applications

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In distributed sensing applications, the strain transfer from the host material to the optical fibre affects the level of accuracy. A novel analytical methodology applied to surface-bonded sensing cables is presented and verified experimentally.
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1. Introduction

The mechanical coupling between the optical fibre sensor (OFS) and the host structure plays a key role in the measurement chain. When the host material is subjected to a certain strain distribution, the shear stress propagates towards the fibre core which asymptotically reaches the same strain level of the structure. In surface-bonded applications, additional protective layers are required to ensure the fibre integrity against harsh environmental conditions. As such, the strain transfer capability is significantly reduced, and must be properly studied to ensure optimal accuracy levels. This study aims to propose a methodology capable to predict the strain profile in the optical fibre core in the case of complex cables bonded over a structure.

2. Methodology

The idea in to consider conventional strain transfer models available in the literature, which are applied to bare embedded optical fibres, and readapt them to predict the response of a complex surface bonded sensing cables. The proposed analytical returns the expected strain profile measured by the interrogator, $\varepsilon_i(x)$, and is described by equation (1):

$$\varepsilon_i(x) = \left(B * \left(G * \varepsilon_f\right)\right)(x) \qquad (1)$$

Where the symbol "*" denotes the convolution operation, *B(x)* is a boxcar filter accounting for the resolution of the interrogator, *G(x)* is a Gaussian filter whose task is to model the transient of the strain profile in proximity of the two ends of the host structure. Finally, $\varepsilon_f(x)$ is the strain profile predicted for a bare optical fibre with a standard shear lag model [1], and is given by equation (2):

$$\varepsilon_f = \varepsilon_h \left[1 - \frac{\cosh(kx)}{\cosh(kL)}\right] \qquad (2)$$

Where $\varepsilon_h(x)$ is the strain value in the host material, *L* represents the length of the structure under test and *k* is the shear lag parameter, condensing the material and geometrical properties of the cable. The model was tested performing several experiments on a sensing cable developed under the PULSe project [2]. An Optical Backscatter Reflectometer™ (OBR 4413) based on the Rayleigh scattering was used as interrogator. The cable was surface bonded on an aluminium specimen and was tested under five loading conditions. Two strain gauges applied to the specimen and were used as reference.

3. Results and Conclusions

Fig. 1 compares together the experimental data (circles), the strain gauges value (horizontal dotted lines), the classical shear lag models (solid lines) and the novel model proposed by the authors (dashed and dotted lines).

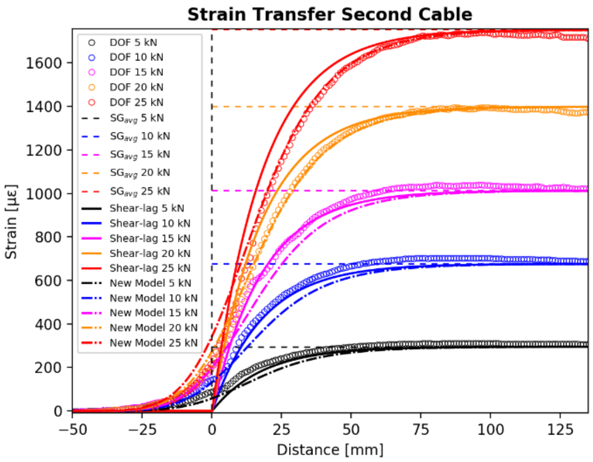

Fig.1 Measured strain profile and model predictions.

This approach allows to predict the instrument response even in the boundary region at the edge of the specimen (vertical dashed line) where traditional models fails.

References

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