PROGRAMA DE DOCTORADO EN INGENIERÍA DE LA CONSTRUCCIÓN

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Title: Optical Multicore Fiber shape sensors. A numerical and experimental performance assessment.

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Abstract:

Structural Health Monitoring (SHM) is a discipline that quantitatively assesses the integrity and performance of infrastructures, relying on sensors, and support the development of efficient Maintenance and Rehabilitation (M&R) plans. Optical Multicore Fiber (MCF) Shape Sensors offer an innovative alternative to traditional methods and enable the reconstruction of the deformed shape of structures directly and in real-time, with no need of computation models or visual contact and exploiting all the advantages of Optical Fiber Sensors (OFS) technology. Despite the intense research efforts centered on this topic by research groups worldwide, a comprehensive investigation on the parameters that influence the performance of these sensors has not been conducted yet.

The first part of the thesis presents a numerical study that examines the effects of strain measurement accuracy and core position errors on the performance of optical multicore fiber shape sensors in sensing three-dimensional curvature, which is at the basis of shape reconstruction. The analysis reproduces the strain measurement process using Monte Carlo Method (MCM) and identifies several parameters which play a key role in the phenomenon, including core spacing (distance between outer cores and sensor axis), number of cores and curvature measured. Finally, a set of predictive models were calibrated, by fitting the results of the simulations, to predict the sensors performance.

Afterward, an experimental study is proposed to evaluate the performance of optical multicore fiber in sensing shape, with particular focus on the influence of strain sensors length. Two shape sensors were fabricated, by inscribing long (8.0 mm) and short (1.5 mm) Fiber Bragg Gratings (FBG) into the cores of a multicore seven-core fiber. Thus, the performance of the two sensors was assessed and compared, at all the necessary phases for shape reconstruction: strain sensing, curvature calculation and shape reconstruction.

To conclude, an innovative approach, based on the Saint-Venant's Torsion Theory, is presented to determine the twisting of multicore fiber and to compensate the errors due to twisting during shape reconstruction. The efficiency of the theoretical approach was then corroborated performing a series of twisting tests on a shape sensor, fabricated by inscribing FBGs sensors into an optical spun multicore seven-core fiber.

The investigation of the mechanical behavior of multicore optical shape sensors has synergically involved diverse disciplines: Solid Mechanics, Photonics, Statistics and Data

Analysis. Such multidisciplinary research has arisen from the prolific cooperation between the Institutes of the Institute of Science and Technology of Concrete (ICITECH) and the Institute of Telecommunications and Multimedia Applications (iTEAM) - Photonics Research Labs (PRL) - of Universitat Politècnica de València (UPV), in addition to valuable collaboration with other members of the European ITN-FINESSE project, to which this work belongs.

This research work aims to enhance the performance optical multicore fiber shape sensors and support the development of new sensor geometries, with great potential for structural health monitoring applications.