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A MICRO-COMPUTER TOMOGRAPHY TECHNIQUE TO STUDY THE INTERACTION BETWEEN THE COMPOSITE MATERIAL AND AN EMBEDDED OPTICAL FIBER SENSOR

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ABSTRACT

Over the last decade, there is growing interest in condition monitoring of large composite structures. Several industrial applications (e.g. Aerospace, Wind industry, Naval industry, Civil infrastructure) are looking for reliable methods, capable of investigating damage evolution during the entire lifetime of the structures employed. In the Wind Energy (WE) sector, for example, there is a need to decrease the cost of the energy production, and therefore they are searching for ways to optimize the Operation and Maintenance (O&M) phase of their wind turbines. Since the WE market is moving towards Offshore application, the difficulty and thus the cost of O&M is increasing.
Among all different sensing techniques, condition monitoring using Optical Fiber Sensors (OFS) appear to be the most suited, because of their high accuracy (±1 µε), their immunity to electromagnetic interference and their small intrusive character when embedded in composite materials [[1]]. Furthermore, OFS technology has also been proven useful as a monitoring tool during composite manufacturing [**Fout! Verwijzingsbron niet gevonden.**].
Although their small intrusive character, still questions are raised on the quality of embedding, the position of the sensor after production, and the to be maintained accuracy of the embedded sensor during the whole life cycle of the composite structure. The present work, therefore, aims to show the potential of micro-computer tomography (µCT) to answer these questions.

High-resolution 3D X-ray micro-tomography is a relatively new technique, which allows investigating the internal structure of samples without actually opening or cutting them. The physical parameter, providing the information about the structure, is the X-ray attenuation coefficient µ, which depends on the local composition of the material of the sample and on the energy of the X-rays. Digital radiographs of the sample are made from different orientations by rotating the sample along the scan axis from 0 to 360 degrees [3]. After collecting all the projection data, the reconstruction process is producing 2D horizontal cross-sections of the scanned sample. µCT has some advantages over other non-destructive technology (NDT): e.g. the high scanning resolution (~2 µm, strongly focused) allow you to clearly identify the damaged zones, the possibility to reconstruct a 3D volume of the investigated region makes it easy to interpret, and an important advantage is the possibility to monitor the specimen each time in between two fatigue test cycles without the need for a “post-mortem analysis”. The µCT gives you information on the embedding process itself: the correct placement of your OFS in the embedding process assures you an accurate measurement (correct interpretation of the strain measured), reducing the possibility of having asymmetric stresses on your sensor (premature damage). For example, the layup of the composite plays an important role in the embedding as can be seen in Fig. 1.

In this work, we have fatigue cycled several cross ply carbon fibre reinforced plastic (CFRP) laminates and followed up the damage evolution around the embedded OFS; all OFS are Ormocer coated.

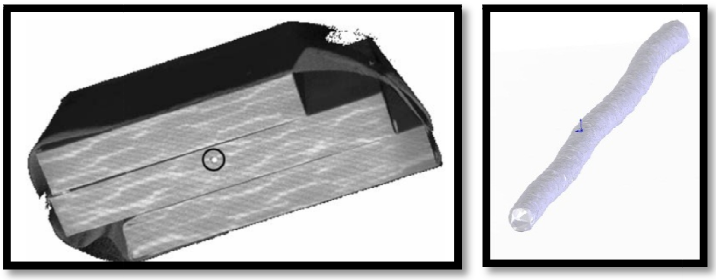

Figure 1: left, 3D-tomography of three samples $[0°,90°]_{2s}$ carbon pps laminate with in the middle section an embedded optical fibre. Right, the microbending to which an OF is subjected in a fabric carbon/PPS laminate.

In Fig. 2 a high resolution µCT – 2D section and a 3D rendering, respectively – are presented. A transverse crack in the proximity of the OFS, as well as the coating surrounding the OFS is clearly visible.

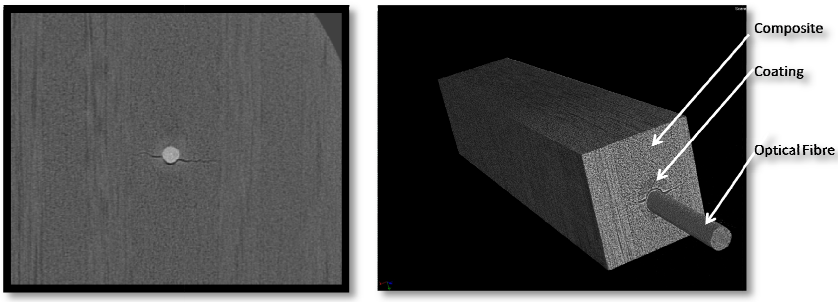

Figure 2: left, 2D cross section taken from a micro-CT of an embedded OFS on a cross-ply CFRP. Right, 3D micro-CT reconstruction of an embedded OFS on a cross-ply CFRP.

By using the µCT technique, it was shown that the quality of the embedding of an OFS in a CFRP can be controlled during the whole life cycle of the composite structure beginning at the stage of the production. This allows us to conclude that using µCT, the quality of different embedding techniques and procedures can be evaluated. The overall goal is to define a reliable embedding method able to ensure adequate accuracy and repeatability that may be implemented in industry. This has partially already been achieved with one of our industrial partners, Airborne (NL), through an automated optical fiber placement process (AFP).

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REFERENCES

[1] G. Luyckx, E. Voet, N. Lammens, J. Degrieck, Strain Measurements of Composite Laminates with Embedded Fibre Bragg Gratings: Criticism and Opportunities for Research, *Sensors*, **11**, 2011, pp. 384-408.

[2] P. Parlevliet, E. Voet, H. Bersee, A. Beukers, Process Monitoring with FBG sensors during vacuum infusion of thick composite laminates, *Proceedings of ICCM 16 Conference, Kyoto Japan*, 2007.

[3] B.C. Masschaele, V. Cnudde, M. Dierick, P. Jacobs, L. Van Hoorebeke, J. Vlassenbroeck, UGCT: New x-ray radiography and tomography facility, *Nuclear Instruments & Methods in Physics Research*

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Section a-Accelerators Spectrometers Detectors and Associated Equipment, **580(1)**, 2007, pp. 266-269.