EXPLOITING THE TEMPERATURE INSENSITIVITY OF THE MODAL BIREFRINGENCE OF MICRO-STRUCTURED FIBRE BRAGG GRATINGS FOR CURE CYCLE MONITORING.

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The project called “Instrumentation with Multi-sensor for Composite Materials and structures (I2MC)” supported by RTRA STAE foundation puts together the expertise of research and industrial teams with the goal to study the in-core instrumentation of composites structures by applying the Multi-Instrumented Technological Evaluator toolbox (MITE toolbox) [1]. In this collaboration, we proposed a multi-instrumentation set up for monitoring a composite structure during its curing phase. The main goal is to show the complementarity of different embedded devices such as flexible ultrasonic transducers (FUT) [2] and micro-structured optical fibres (MOF) [3], in order to infer the initial state of the composite structure by means of its residual strains. The composite structure studied here is a M10 HS300 carbon-epoxy plate of 230 x 640 mm with two drop-off zones as shown in Figure 1. The composite plate has three zones with different thickness. In first place, the “current zone” has 20 plies with a quasi-isotropic lay-up: [0/45/0/-45/0/45/0/-45/0/90]s. Then, the “thick zones” have 36 plies with the following lay-up: [0/45/0/-45/0/45/0/-45/0/90/0/45/0/-45/0/45/0/-45]s. Finally the “over-thick zone” has 50 plies with the next lay-up: [(90/0/0/90/0/45/0/-45/0/45/0/-45/0/90/0/45/0/-45/0/45/0/-45/0/90/90/0]s. The drop-off zones are built with a 2.5 mm single latter step from the 11th ply to the 26th ply. This type of structure is representative of the design singularities currently found in aeronautics.

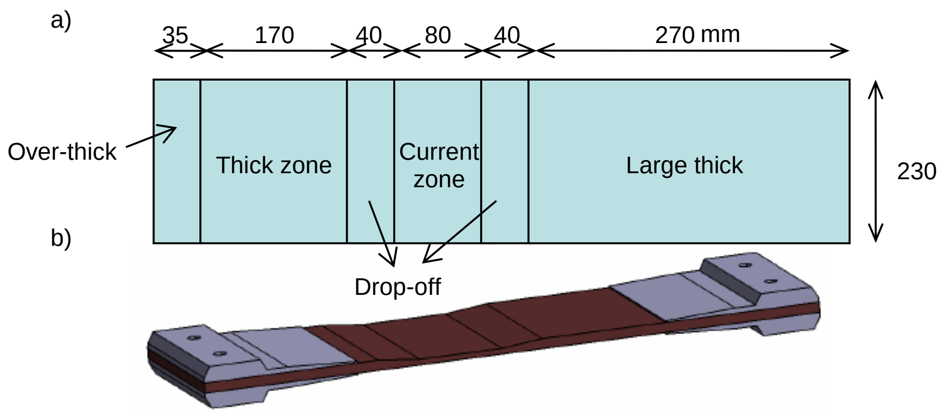

Figure 1. Geometry of the composite structure with two drop off zones (a) and a global view with the jaws (b).

An assembly of flexible ultrasonic transducers (FUT) are placed to follow the thickness evolution of the composite plate. The measurements of the ultrasonic waves can reveal the physical state of the composite plies. The evolution of the time delay during the curing cycle is analyzed which can be a measure for the different phases of the cure cycle. The curing phases are identified with a unique signature beginning with the mould-composite coupling, passing through resin reticulation and finishing with composite consolidation. With these recognizable signatures, the viability of FUT to estimate the composite polymerization evolution is proven. In addition MOF fibre Bragg gratings are used to monitor strain evolutions during curing. MOF FBGs are written in a fibre with a specialized design for purpose. In this case, the MOF is designed to be more sensitive in the transverse direction of the fibre which allows us to measure very small strain differences during curing in the transverse directions and in the longitudinal direction. The fibre shape is not completely round which forces the fibre to maintain its correct orientation in the structure, however orienting the is still necessary. Nevertheless, with this new technology of micro-structured optical fibres (MOF), the evolution of peak separation for the embedded FBG is shown and it allows qualitative indications of the appearance of transverse strains from the beginning of the cooling stage until composite consolidation. These transverse strains are directly linked with the appearance of residual stresses within and between the composite plies. The calculation of the magnitude of residual stresses (quantitative analysis) will be treated in upcoming studies.

[1] F. Collombet, M. Mulle, YH Grunevald, R. Zitoune. **Contribution of the embedded optical fiber with Bragg grating in composite structures for tests-simulations dialogue**. Mechanics of Advanced Materials and Structures, 2006; 13: 429-439.
[2] M. Kobayashi, C-K. Jen. **Piezoelectric thick bismuth titanate/PZT composite film transducers for smart NDE of metals**. Smart Materials Structures 2004; 13: 951–956.
[3] C. Sonnenfeld, S. Sulejmani, T. Geernaert, S. Eve, N. Lammens, G. Luyckx, E. Voet, J. Degrieck, W. Urbanczyk, P. Mergo, M. Becker, H. Bartelt, F. Berghmans, H. Thienpont. **Microstructured Optical Fiber Sensors Embedded in a Laminate Composite for Smart Material Applications**. Sensors 2011, 11, 2566-2579; doi: 10.3390/s110302566.