Process and Structural Health Monitoring of a "smart" Polymer-Matrix Composite using an in-situ piezoelectric sensor.

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ABSTRACT

Polymer-Matrix Composites (PMCs) are increasingly used nowadays in high-tech industries, such as aeronautics, aerospace or automotive, due to their very interesting mechanical properties combined with an unequalled lightness. However, as these industries have very demanding standards, these materials must fulfil a lot of criteria, such as high dimensional tolerances, high mechanical properties to survive various kinds of physical loadings, or important resistance to harsh environments (thermal ageing, radiation, corrosion, etc.). To succeed in passing all these tests, composite parts must be checked in every steps of their life, from the manufacturing step to the end of their utilization. That is why their manufacturing (Process) Monitoring (PM) and Structural Health Monitoring (SHM) are relevant. It helps to understand if the produced composite parts are of sufficient quality (porosity amount, preform impregnation quality, dimensional tolerances) to be used in service, and how they will behave during their industrial exploitation (damage initiation and progression, checking or permanent replacement thresholds). To perform PM and SHM, Non-Destructive Testing (NDT) techniques can be used, such as Acoustic Emission (AE), Infrared Thermography (IRT), Ultrasonic measurements and so one. However, as the corresponding devices are often cumbersome, they cannot permanently remain on the structure to survey. Integrating those devices into these structures becomes thus of particular interest. A lot of studies being currently undertaken on this innovative subject [1], the authors wanted to follow this promising tendency, by conducting both in-situ PM and SHM experiments of a PMC material thanks to an integrated piezoelectric disc sensor. The manufacturing of the studied "smart" glass/polyester laminate specimens was performed using liquid resin infusion technique, a piezoceramic PZT disc being inserted at the heart of the fiber stack to perform continuous electrical measurements (capacitance) during the whole manufacturing process. To help understanding the in-situ sensor output signals, a multi-instrumentation system involving several external and internal NDT techniques (IRT, AE, thermocouples, pressure sensor, Z-displacement transducers) as well as chemo-physical measurements (DSC, rheology) conducted on the curing resin alone were employed, and multi-physical couplings were found between these different signatures. These couplings shed some light on how in-situ electrical capacitance of the PZT disc can be sensitive [2] to the resin injection step, and then to the various transition stages happening during resin curing (gelation, vitrification). After manufacturing, the specimens were submitted to cyclic tensile loading, to evaluate both in-situ PZT disc intrusiveness and its SHM abilities when following its electrical capacitance variation. These tests, multi-instrumented with AE and stereo digital image correlation (SDIC), showed that electrical capacitance was following well the cyclic loadings, and could be used to give an evaluation of the damage initiation and progression when confronted with AE and DIC measurements.

REFERENCES

[1] C. Tuloup, W. Harizi, Z. Aboura, Y. Meyer, K. Khellil, and R. Lachat, "On the use of in-situ piezoelectric sensors for the manufacturing and structural health monitoring of polymer-matrix composites: A literature review," *Compos. Struct.*, vol. 215, no. December 2018, pp. 127–149, 2019.

[2] N. Elvin, A. Elvin, and B. Z. Senderos, "Capacitance changes in thin piezoelectric transducers embedded in isotropic host materials," *J. Intell. Mater. Syst. Struct.*, vol. 29, no. 5, pp. 816–829, Mar. 2018.