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ACOUSTIC EMISSION ANALYSIS ON CFRP LAMINATES SUBJECTED TO OPEN HOLE TESTING

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Abstract: *Carbon Fiber Reinforced Plastic materials (CFRP) are widely used for aeronautical and aerospace applications since they offer high specific mechanical properties. However, their damaged behavior is quite concerning and, if these damages are not visible on the surface their use could become deeply dangerous if not properly monitored. It is therefore essential to detect, evaluate and analyze the several types of propagation of damage caused by static, cyclic and environmental effects. Acoustic Emission technique (AE) is an innovative practice that is providing good results in detecting and identifying CFRP damages. In this paper, the AE technique was applied to CFRP specimens subjected to open hole testing.*
Keywords: *Acoustic Emission, CFRP, Open Hole*

1. INTRODUCTION

Composite materials are widely used in industrial structures. In particular, carbon fiber reinforced plastics (CFRP) offer high specific mechanical properties (a good stiffness to weight ratio, and a good strength to weight ratio). Thus, during the last decades, they have been increasingly used as components of structures having essentially mechanical functions, particularly in aeronautical and aerospace applications. Their damaged behavior is quite concerning. There are different damage modes, but not enough good models to describe them. It is therefore imperative to detect, evaluate and analyze the several types of damage propagation caused by both static or cyclic loads and by environmental effects too. So, it is possible to work in two ways to solve this problem: the minimum detectable size could be increased to extend the maintenance window, requiring the use of more precise inspection techniques and growing costs; or the critical defect size could be increased by using more material, defeating the initial benefit of using a composite material to save costs and reduce the weight.
Although traditional non-destructive techniques enable a posteriori detection of damage at successive stages of the life of these materials, it seems more difficult to monitor in-situ the evolution of internal damage nucleation and growth, especially in opaque materials. The Acoustic Emission (AE) technique is now used to detect and possibly to identify damage mechanisms in CFRP. This is achieved by analyzing AE parameters like the amplitude event, the energy and both the number and the duration of each event. It is critical to achieve a relationship between amplitudes and rupture mechanisms. In spite of this, several studies confirm that low amplitudes are correlated with matrix cracking, medium amplitudes with delamination and high amplitudes with fiber breakage.

2. MATERIALS AND METHODS

Experimental campaign involves 7 open hole tensile specimens belonging to two laminates characterized by different resins reinforced by carbon fibers. Four specimens refer to carbon/thermoforming resin laminate, three specimens refer to carbon/thermoplastic resin laminate. Both laminates have the same lay-up [(0,90)4]s. They are tested according to ASTM 5766 standard [1]. For ease of working the first laminate is named A and the second one is named B.
Specimens have rectangular shape section and uniform thickness (36 mm width, 3.04 mm thick for A and 2.48 mm thick for B), and they are 200 mm long.
Tests were carried out at environmental controlled conditions, 23 °C, and at constant displacement rate of 2 mm/min on a servo hydraulic loading machine, Schenk 1342.

Acoustic emission events were recorded by using Acoustic Emission software AEWin and a data acquisition system Physical Acoustics Corporation (PAC) PCI-2. To detect Acoustic Emissions two piezoelectric sensors [2, 3] were coupled with samples by a silicone gel. Each AE sensor is resonant-type, single-crystal piezoelectric transducer from PAC. Its main characteristics are reported in Table 1.

Table 1: Characteristics of the Pico Sensor

Peak Sensitivity	54 dB
Operating Frequency Range	200 – 750 kHz
Resonant Frequency	250 KHz
Temperature Range	-65 to 177 °C
Dimension	5 x 4 mm

Figure 1 reported the schematic sample and the load fixture used for the execution of the test.
Acoustic emissions acquisition frequency was set to 100 kHz in consideration of the duration of the test. A threshold value of 35 dB was chosen. The signal was detected by the sensor and enhanced by a 20/40/60-AST preamplifier. The gain selector of the preamplifier was set to 40 dB. In order to determine the instantaneous crack tip position, at first, AE wave velocity in the specimens must be specified. The velocity of the AE waves in the specimens was evaluated using standard pencil lead breakage test.

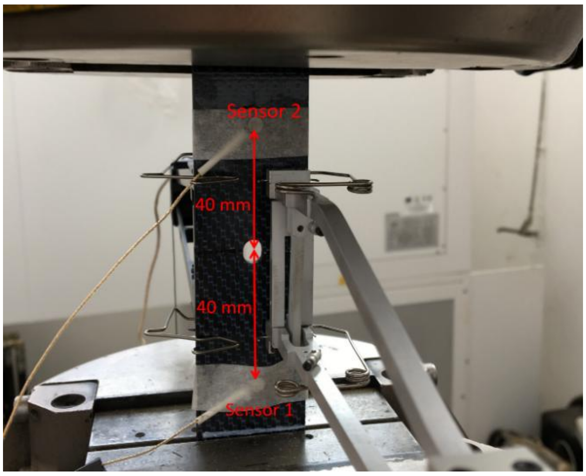

Figure 1: Schematic loading fixture for Open Hole Tensile test

3. RESULTS

Looking at the graphs, reported below, it results very interesting to observe the significant difference occurring in Energy values between the two different laminates. For laminate A the Energy reached the value of 16000, on the other laminate, instead, the maximum value obtained is limited to 450. Despite this deep difference, the trend appears quite similar. In fact, we can distinguish three zones: in the first one (up to 40% of duration life) the Energy values are very low (approximately 0); in the second zone (from 40 % to 80 % of duration life) the Energy values are higher than the previous ones; the third zone (from 80% to 100% of duration life) show the highest value of Energy.
It is important to underline, also, that from Figure 2 it can be obtained another important data referring to the nature of the thermoforming matrix of laminate A. In fact, thermoforming resin are generally more resistant and harder than the thermoplastic ones but also more brittle.
This attitude is explained by the acoustic signals through deep jumps and global higher values of Energy curve.
Moreover, looking at **Error! Reference source not found.** it could be seen the different effects of matrix and fibers on acoustic signals. In fact, according to scientific literature, lowest Energy signals are linked to matrix events (I zone) while highest Energy signals are due to fibers events (III zone). In the II zone, it can be observed a combination of signals which correspond to an increasing value of

Energy and Hits/sec respect to I zone but lower than the III one. They are probably due to the starting breakage of fibers respect to the total breakage of them in III zone.

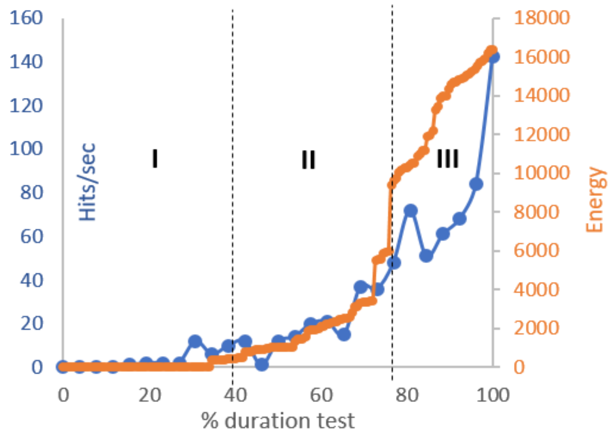

Figure 2: Acoustic emission signals for laminate A in terms of Hits/sec and Energy

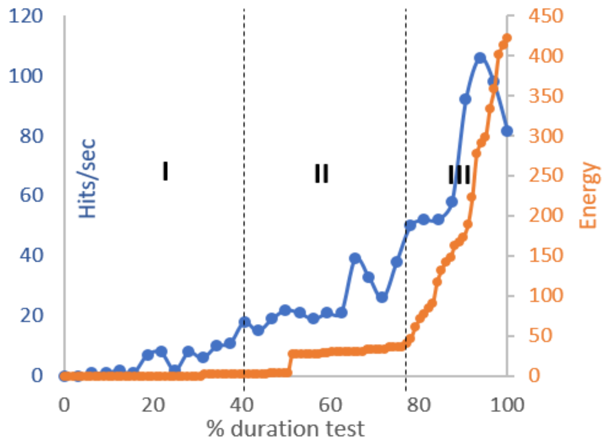

Figure 2: Acoustic emission signals for laminate B in terms of Hits/sec and Energy

4. CONCLUSION

In this paper, AE technique is applied on open hole tensile specimens. This approach intends to obtain predictive information about the state of material relating to the composite nature. It seems to work in a good manner, since it provides interesting and promising data indicating not only the fracture occurring but also distinguishing the matrix signals from the fibers ones.

REFERENCES

[1] ASTM 5766 - Standard Test Method for Open-Hole Tensile Strength of Polymer Matrix Composite Laminates, 2011.

[2] M. Enoki, T. Kishi and S. Kohara "Determination of Microcracking Moment Tensor of Quasi-Cleavage Facet by AE Source Characterization" Progress in Acoustic Emission III, Proceedings of the Eighth International Acoustic Emission Symposium, The Japanese Society for Non-Destructive Inspection 763-770, 1983.

[3] www.mistrasgroup.com