A comparison between Acoustic Emission and Thermography on impact damage assessment of carbon fiber materials

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Abstract. The present work deals with the comparison between Acoustic Emission and Infrared Thermography for the non-destructive damage assessment of carbon fiber reinforced polymers before and after impact testing. Tensile tests and four-point bending tests on both undamaged and damaged specimens were performed. During the tests both techniques were applied to evaluate the damage development and to assess their capabilities in identifying, localizing and assessing the damage in specimens, in light of an application to full-scale structures. The results of acoustic emission testing are also processed with a neural-network based classifier, to highlight the different damage modes that may have developed in the specimens.

Introduction

Carbon fiber reinforced polymers (CFRP) are widely used in different structural applications, mainly in the automotive and aerospace industry, mainly for their attractive strength-to-weight ratios. These materials, however, are very sensitive to impact damage, which may lead to the development of delamination, thus causing unexpected and dangerous load bearing capability drops or reduce residual fatigue life. Furthermore, it is very difficult to detect this type of damage in big structures, because they tend to develop inside the material or in the opposite side of the impacted region, thus making it nearly impossible to detect via routine visual inspections.

Traditional non-destructive techniques (NDT), such as ultrasonic inspection or radiography, are either too local (ie. they are capable to inspect only small areas at once) or too expensive in terms of time or money. Their application is sometimes not feasible for example in aircraft inspections, where the maintenance time is one of the highest costs, requiring both non-operating time (and therefore revenue loss) and highly specialized personnel requirement.

Infrared (IR) Thermography is based on measuring small temperature changes in the surface of a material [2]. The difference in these temperature changes may be related to the presence of internal defects, which alter the thermal conductivity of the material, or the development of the defects themselves, releasing part of their bonding energy in form of heat. Special cameras, operating in the infrared band, can measure the surface temperature field with sufficient accuracy to detect these phenomena.

Acoustic Emission (AE) is a NDT which is based on the monitoring of surface ultrasonic waves related to damage development. It is established [3] that AE signals (usually referred to as “hits”) are related to damage development; furthermore many authors believe that waveform parameters can be related to the type of damage mode which has originated them. Also, the source of the waveform can be located with some degree of accuracy, namely with time of arrival (ToA) based algorithms or advanced mapping methods, such as the Delta-T technique [4].

Materials and methods

The material used for this work consists of a CFRP laminate, 41% fibers in volume, with a symmetrical layup sequence of [+45/-45/0/90]2s. The resulting laminate thickness was on average of 2.5 mm. The stacking sequence was chosen in order to reach a high level of isotropy and, according to [5], to have an overall satisfactory impact energy adsorption performance. The material was produced in 200mm x 200mm square panels. To assess and compare the performance of the two NDT techniques kind of tests were performed: static tensile tests and four-point bending tests. Both techniques were applied to non-impacted and impacted specimens.

Impact testing. A drop-weight impact test was used to damage the central part of each panel. The energy of the impact was approximately 15J, which correspond to a 1.9 kg mass dropped from 90mm height. The mass velocity was measured with a laser gate, which allowed to correct for air and friction energy loss during the mass travel in the steel tube. The panels were then cut considering the impacted region as “damaged” and the farther regions as “undamaged”.

Tensile tests. Undamaged specimens of 200x25mm size, with aluminium tabs bonded, were loaded with a constant crosshead speed (1mm/min). These specimens were monitored with IR Thermography and AE;
due to specimen space constraints only two AE sensors were used, thus allowing only linear localization of the recorded AE signals.

Damaged specimens were cut in 200x45mm rectangles and got aluminium tabs bonded too. The same testing condition of undamaged specimens applied; however the bigger size of the specimens allowed to use 4 AE sensors, and therefore planar localization of signal sources.

**Bending tests.** Damaged and undamaged samples, sized 200x65mm, were tested in a four-point bending-test setup. The short span (loading side) was set to 50mm, to enclose the impacted area in the constant-bending section of the specimen; the long span (support side) was set to 150mm. Due to space constraints, these tests were not monitored with IR thermography.

**Results**

IR thermography (Figure 1) and AE data from tensile tests confirm that the damaged specimens show a higher energy release from the impacted region of damaged specimens than from the undamaged specimens.

![Figure 1: Temperature - stress trend for a undamaged (a) and impacted (b) specimen.](image)

AE data from bending tests allowed to localize and assess the presence of the impact damage in the three monitored samples, while showing significant less energy release in the undamaged samples (Figure 2).

![Figure 2: AE energy by XY location of impacted (left) and undamaged (right) specimens during bending tests](image)

**References**