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ScienceDirect

Procedia Structural Integrity 3 (2017) 237–245

Structural Integrity Procedia

www.elsevier.com/locate/procedia

XXIV Italian Group of Fracture Conference, 1-3 March 2017, Urbino, Italy

Experimental determination of thickness influence on compressive residual strength of impacted carbon/epoxy laminate

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Abstract

An experimental campaign was performed on 5.5 mm thick carbon/epoxy specimens and results were compared with data obtained in a previous work to understand thickness influence on material mechanical characteristics. In particular, this campaign consists of two different steps: impacts tests, performed by means of a modified Charpy pendulum, and Compression After Impact (CAI), using Wyoming Combined Loading Compression (CLC) test method. Impacts were performed on twenty cross-ply specimens with different energies and impact location. Other 5 specimens were tested only in compression. Non Destructive Inspections (NDI) by Ultrasonic Test (UT) were performed on impacted and pristine specimens, in order to understand damage size and correlate it with residual strength results. During CLC tests, compression strength and Young modulus values were acquired.

Keywords: CFRP; impacts; BVID; CLC; CAI; NDI; UT

Nomenclature

ASTM	American Society for Testing and Materials International
BVID	Barely Visible Impact Damage

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Peer-review under responsibility of the Scientific Committee of IGF Ex-Co.
10.1016/j.prostr.2017.04.056

CAI	Compression After Impact
CI	Central Impact
CLC	Combined Loading Compression
NE	Near Edge
NDI	Non Destructive Inspection
PE	Pulse Echo
TT	True-Transmission
UD	Unidirectional
UT	Ultrasonic Tests

1. Introduction

In aeronautics, as well as in automotive, the most important aim of industries has always been making lighter and safer vehicles. This is the principal reason that sustained composites rise in these two fields. These materials have high strength-to-weight ratio but unfortunately their behaviour under operative conditions is still not completely known.

For automotive field, unknowns issues are not as delimitating as for aeronautical: applied safety factors are not as high as for aeronautical industry, where operative conditions are extreme. Moreover, all composite structures in aerospace vehicles have to satisfy the 'no-growth' principle [Composite Material Handbook (2012)]. This means that during static and dynamic tests (e.g. fatigue) a composite structure has not to show either damage initiation or growth of existing flaws.

Many factors could create damages in composite elements: hygro-thermal aging, lighting strikes, impacts, etc. Most of them are avoided by means of additional structure protections or prevention. On the other hand, impact occurrence is not predictable due to many possible causes: maintenance tools drop, debris, luggage loading, bird strikes, hail. It is, therefore, necessary to better understand composites response to impacts and their subsequent residual strength [Abrate (1994) & (1998)].

Hence, impact tests are performed at different level of airplane design, from coupon dimensions to panel or substructure. Tests are also conducted with different aims: at sample level they are usually done to understand material mechanical characteristics while, when they involve a real structure, principal aim is to check actual resistance, limit and ultimate load bearing capability.

Furthermore, depending on impact energy and velocity, resulting damages could be different. High specific energies conduct to evident defects that must be repaired; lower energies do not result in any clue on external surfaces but might create wide internal damages. The latter is the worst scenario: during inspections, first step is visual inspection; after this, if a damage is detected, more accurate NDI are used. Therefore, if surfaces do not show any external evidence of an internal damage, it would be possible to overlook something potentially dangerous. This kind of damages are known as BVID (Barely Visible Impact Damages).

In this contest, authors worked to better understanding carbon/epoxy laminate behaviour under BVID. First step results are reported in Falaschetti et al. (2015) where a thin carbon/epoxy laminate was tested under compression after low energies impacts to estimate their influence on mechanical strength. It was demonstrated that impacts quite badly influence the compressive strength. Moreover, impact position influences material strength over a certain energy level, defined as 'energy threshold' for that kind of geometry.

An experimental investigation, which could clarify material thickness effect on impact damages, has been performed.

2. Experimental

2.1. Specimens

Twenty-five specimens were cut from a carbon/epoxy laminate. This was made by means of hand-lay-up of 17 pre-preg unidirectional (UD) plies. Stacking sequence was chosen to obtain a symmetric balanced laminate: $[(90/0_2/$