AN EXPERIMENTAL METODOLOGY AND APPARATUSES TO PERFORM IMPACT TESTS IN COMPOSITE LAMINATE PLATES

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Introduction

During manufacturing, maintenance, storage and operation the structures made of composite materials are particularly susceptible to be accidentally damaged by a dropped tool, runway debris or from another types of objects, which if occur can lead to a significant strength reduction in post-damage performance.

The transverse impact is extremely important because the resultant damage cannot be visible and by the fact that in this direction the composite material has low resistance, because of the absence of fibers. The impact loads when occur can produce a damage area, reducing ample the mechanical stiffness, leading to the material failure in different modes: matrix failure, fiber failure, compression failure, fiber winking, and interlaminar delamination [1,2,3,4].

This research aim to develop an effective and useful procedures and methodologies to analyze and validate new materials for the aerospace industry.

Experimental

Description of the Drop Tower Test Facility

The impact tower used tall 7 meters and consists basically of a guided striker to fall from a pre-determined height and hit the coupon at its center. The impact force acquisition is done through a piezoelectric load cell incorporated on the impactor. The load cell is a half spheric cylinder with 12.5 mm diameter, supplied by Pcb Piezotronics®, model: 208A3, type: Icp Dynamic Force Sensor, with a nominal Sensitivity of 0.227 mVolts/g and measuring range of 44.48N to 22.4 kN. A photo sensor is used as a trigger to initiate the data recording and two strain gages were utilized in each coupon face to verify the bending strain levels.

The main hardware is composed by an 8-channel signal conditioner module for piezoelectric accelerometer model NI® SCXI 1531, an 8-channel linear-voltage differential transformer (LVDT) module model NI® SCXI 1540, an 8-channel universal strain gage input module model NI® SCXI 1520 assembled into a chassis unit model NI® SCXI 1000.

The software Labview® version 8.2 was used to data acquisition and for this work a specific Virtual Instrument (VI) routine was developed to acquire the data obtained by the photo sensor, the strain gages and the load cell. Other electronic component used was a signal amplifier which was mounted to increase the toke coming from the photosensor. A computer desktop with a Pentium® 4 of 3 GHz and an acquisition board model NI® PCI 6052E completes the impact test data acquisition system. The load cell, the photo sensor and the strain gages were connected into the signal conditioner.

On the striker was attached a black and white ruled scale for data acquisition beginning and also to measure velocity. After the data recording the software Microsoft Excel was used for data treatment and charts plotting.

Impact tests

In order to carry out the impact test, the coupons are fixed in the middle of a metallic rectangular frame which is clamped with bolts on the drop tower in all the four edges. The coupons dimensions and the strain gages location are shown on Fig (1.a) and Fig. (1.b).

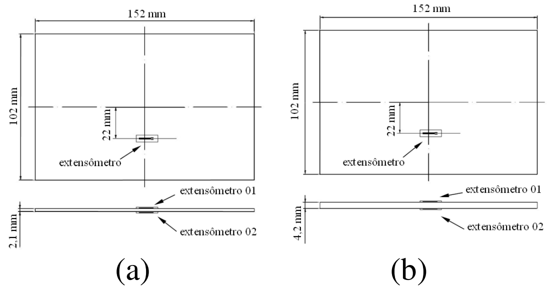

Figure 1. 10 layer laminate dimensions, and strain gage locations (a), 20 layer laminate dimensions and strain gage locations (b).

Below on table 1 are listed the main laminate properties and the tests characteristics.

Table 1. Test characteristics and laminate lay-up

Test	Lay-up	Energy level	Height (meters)
1	$[\pm45/(0,90)/\pm45/(0,90)/\pm45]_S$	Low	0.48
2	$[\pm45/(0,90)/\pm45/(0,90)/\pm45]_S$	Medium	1.00
3	$[\pm45/(0,90)/\pm45/(0,90)/\pm45]_S$	High	1.77
4	$[\pm45/(0,90)/\pm45/(0,90)/\pm45/\pm45/(0,90)/\pm45/(0,90)/\pm45]_S$	Low	0.81
5	$[\pm45/(0,90)/\pm45/(0,90)/\pm45/\pm45/(0,90)/\pm45/(0,90)/\pm45]_S$	Medium	1.5
6	$[\pm45/(0,90)/\pm45/(0,90)/\pm45/\pm45/(0,90)/\pm45/(0,90)/\pm45]_S$	High	2.05

In this work the tested laminate thickness are follow: 2.1 mm (10 layer, layer thickness = 0.21mm); 4.2 mm (20 layer, layer thickness = 0.21mm). The tested lay-up is quasi-isotropic and three impact energy levels for each laminate thickness were selected: For the 10 layer laminate the energy levels were: low energy: 8 Joules; medium energy: 16 Joules; high energy: 28 Joules. For the 20 layer laminate the energy levels were: low energy: 12 Joules; medium energy: 24 Joules; high energy: 32 Joules. Three coupons were tested, for each energy levels and thickness.

Results and Discussion

As an illustrative example only the results for the 20-layer-laminate and one energy level are shown, the other results can be seen elsewhere [1]

The velocity history time was obtained by the force integration and similarly the displacement history time was acquired by the velocity integration.

The data were recorded using 50 kSamples/s, i.e., data recording in each 0.02 ms which results in more than 170 points.

The impact peak loads were 6272.2; 6412.1 and 6388.8 N and the impact duration were 3.36; 3.32 e 3.4 ms (Fig. 2).

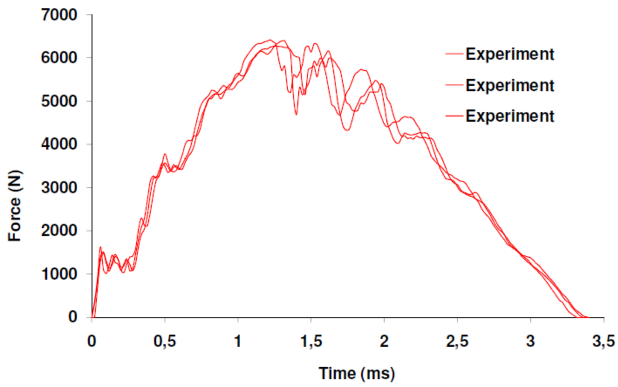

Figure 2. Force histories vs. time at low energy

On Fig. 3, were depicted the displacement history time undergo by the coupons after the impact. The minimum and the maximum deflection were 3.7 and 3.9 mm respectively.

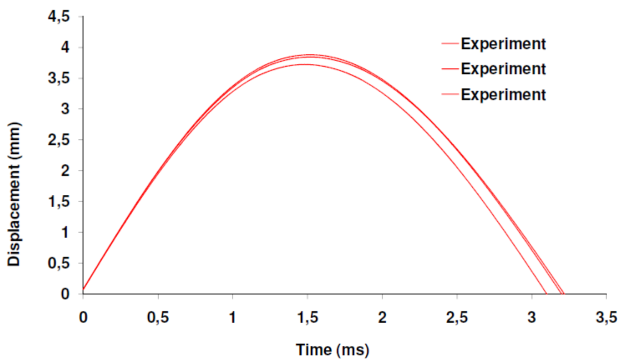

Figure 3. Displacement histories vs. time at low energy

The Fig. 4 reports the strain history time. The negative strain occurred due to the compression and is associated with the strain gage bonded on the coupon top surface. On the other hand, the positive strain is related the strain gage fixed on the specimen bottom surface which experience tensile loads. The velocities are got by the force integration. On the impact moment the maximum velocity was 4.05 m/s and the velocity rebound was 3.7 m/s.

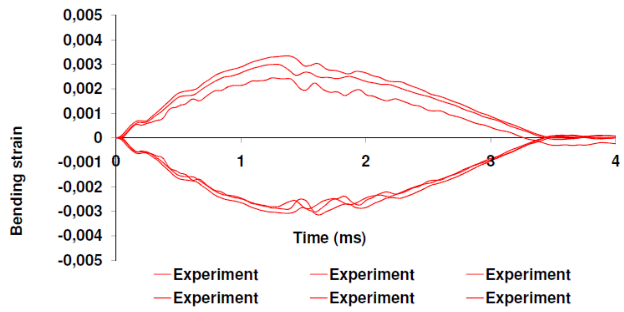

Figure 4. Bending strain at low energy

Conclusions

The experiment setup designed is capable of measuring impact forces at impact velocities up to 7 m/s using an instrumented projectile load cell. Using some weights on the impactor is possible to achieve energy up to 70 joules. This work presented a experimental study of the composite laminate structural behavior under impact loadings. The methodology was shown to be effective in perform impacts on composite laminate plates in accordance with international standards.

The main damage mechanism observed during the low energy impacts was delamination and fiber failures occurs at higher energies, accompanied by a noticeable delamination area.

Acknowledgments

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