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An Experimental Study of Damage Accumulation in Balanced CFRP Laminates Due to Repeated Impact

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Introduction

Structural components manufactured from fibre-reinforced plastics are increasingly used in situations where high strain loading is present. The relative importance and increasing demand for these composites in industrial applications is among other things due to their high strength to weight ratios, high fatigue strength, high static strength, high-energy absorption, corrosion resistance and ease of manufacturing particularly into large shell structures.

At least 50% of the next generation of military and civil aircraft structures are likely to be made from composites [1]. The behaviour of CFRP composites under high strain loading such as impact, slam etc is more complex than monolithic materials because of the factors that influence the damage mechanism, which include the fibre material, matrix material, volume fraction, fibre orientation, moisture content, porosity, strain rate etc.

The aim of the present work is to assess and compare the characteristics of balanced carbon fibre laminates based mainly on repeated drop tests, assuming the interest is the use of a balanced lay-up and therefore to report the behaviour of these laminates to repeated impulsive loadings. A balanced laminate can be symmetric, antisymmetric or asymmetric as shown below.

- Symmetric: $[\pm\theta_3/\pm\beta_3]_s$
- Antisymmetric: $[\theta_6/\beta_6/-\beta_6/-\theta_6]$
- Asymmetric: $[\theta_6/\beta_6/-\theta_6/-\beta_6]$

The choice of the laminate depends on what the designer wants to achieve as components can be tailored to the needs of a project.

Manufacturing process

Using $60^0$and 45^0 squares and blades appropriate sizes of laminae were cut from the roll of CFRP prepregs lamina manufactured by Hexcel®. Stacking of the plies to form the laminates was made manually. The samples were covered with a release film, and placed between aluminium plates on the bed of an autoclave.

This was covered with a bleeding material and a vacuum bag and sealed round its perimeter with a tape. A vacuum pump was connected to the valve fitted to the bagging material. Air was extracted and curing was accomplished in an autoclave.

Impact testing facility

For this study a *ROSAND* instrumented drop weight tester was used. The basic requirement of the instrumented falling weight test is to gain an understanding of the mechanism by which materials or structures fail in impact situations ie at high rates of strain. During the impact, the resistive force exerted by the sample on the striker is measured as a function of time and stored for subsequent display and analysis. That is the force transducer detected the contact forces at many consecutive instants and transient data were recorded for the sample tested, which included time, energy, velocity and deflection. The fracture event lasts, typically for a few thousandths of a second.

To ensure the reliability and confidence of the data from the instrumented drop tester, three non-penetrating tests were conducted on 10 mm thick aluminium plates. The drop height was 0.03m ie impact energy of approximately 8.8J for the aluminium plates. There are six parameters that define the data capture process: amplifier gain, capture rate (sweep time), number of points, trigger source, trigger level and pre-trigger percentage. The sweep time is very important as it sets the data acquisition speed of the drop tester. In order to preserve as much accuracy as possible for the test, it was set to 50 microseconds per data point.

The results of these preliminary tests were plotted. These plots are identical and highlight the repeatability and consistency. The peak load in each event was about 14kN and the total energy approximately 5.7J, in all the tests conduct on the aluminium plate.

Test results

Macroscopic damage modes of the composite laminate after impact include indentation, surface cracking, delamination, back face splitting and laminate splitting. The split ply at the back face followed a pattern of cracks that reproduces the fibre directions.

Transient data were obtained as a result of drop tests on three types of balanced laminates, namely: symmetric, antisymmetric and asymmetric. The results (an example of which is given in *Fig 1)* obtained show that the symmetric laminate with dissimilar interfaces, has best endurance against repeated low energy impact. Dissimilar interfaces here refer to the reinforcement fibre direction. The difference in endurance limits of the laminates were attributed to the interlaminar – intralaminar crack paths of the three kinds of balanced laminates. For all the composite plates, the perforated surfaces revealed the fibre orientation of the rear laminae, ie matrix cracking and back face splitting. Perforation was defined when the striker completely moved through the laminate.

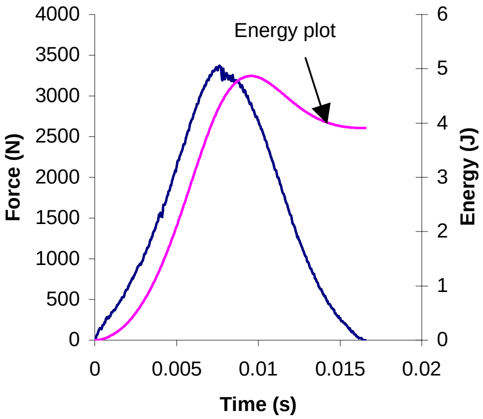

Fig 1 Typical force and energy histories due to 6J impact on a symmetrical composite plate

The data correlating the absorbed energy and the impact events reveal that the response is dependent on the plate configuration and the crack path. This was well delayed by the symmetric plate giving some warnings before perforation. The progression of damage in the impact event was connected to the formation of the failure mechanisms, by correlating the energy profile to the contact time, giving a sixth order polynomial, which was differentiated to develop a rate for the damage formation.

Bending stiffnesses of the laminates were estimated from the force – displacement plot and the symmetric laminate gave the best resistance to impact. In general, the balanced symmetric composite has proved to be much safer in respect of impulsive loading.

Reference

1. http://www.netcomposites.com/news.asp?3869