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Experimental Evaluation of ILSS and Flexural Strength of Hybrid Composite Laminate

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ABSTRACT:

Carbon fiber reinforced composite materials due to their light weight, low density, high specific strength, corrosion resistant, high stiffness and strength properties have always been widely used for aircraft and space craft applications. Recent development in the aircraft industry substantially improves fuel economy and extending flight range has accelerated interest in the use of advanced composites as primary structures. Above 85% the surface area of the advanced light helicopters are made of fiber composite structures. There are different DT and NDT method to evaluate and analyze the strength of these test specimens out of which the ILSS & FLEXURAL is the DT method to characterize the bonding strength of the fiber/epoxy composite material. Hence in this project the efforts are made to analyze and evaluate the experimental evaluation of apparent ILSS and FLEXURAL strength of CFRP and hybrid composite laminate. Specimens are prepared as per the DIN 29971 standard for ILSS and DIN 53452 Standard is followed for flexural test. NDT tests were carried using ultrasonic “c” scan and the DT (ILSS) were carried by varying the UTM speed in increments with 2mm/min. The Experimental work will be a base line for calculating the actual strength made with different orientation by the designers and manufactures to manufacture the component and to achieve better components.

Keywords:
Fiber composites, ILSS (Inter laminar Shear Strength), DIN (Dutch Institute of Norms), DT (Destructive testing), Flexural strength, NDT (Non Destructive Testing).

1 Introduction

A composite material may be defined as one, which contains separately identifiable two or more dissimilar constituent materials, in its initial uncured state and in the final solid cured form. Glass fiber is the most widely used fiber in FRP industry consistency for composite applications have been available since the 1930‟s. They are made by rapidly drawing molten glass through relatively large number of orifices at a high speed. The filaments are cooled rapidly, coated with a surface protective coating called sizing and collected as a bundle of strands (bunch of filaments) by winding it on a stable cylindrical package. Carbon fiber (sometimes called graphite fiber) possesses both high fiber modulus (330 – 350 GPa). and high fiber strength (3.0 – 3.3 GPa). Carbon fiber can be made from a variety of organic or petroleum polymer fibers. The two most widely followed carbon fiber manufacturing processes are the ones based on Polyacrylonitrile (PAN) precursor and the other on Petroleum pitch.

2 Fabrication Process

2.1 Hand Lay Up

Hand lay- up molding is used for the production of parts of any dimensions such as technical parts with a surface area of a few square feet. This method is generally limited to the manufacture of parts with relatively simple shapes that require only one face to have a smooth appearance (the other face being rough from the molding operation). It is recommended for small and medium volumes requiring minimal investment in molds and equipment‘s.

2.2 Vacuum Bagging

Vacuum bagging is a technique employed to create mechanical pressure on a laminate during its cure cycle. Pressurizing a composite lamination serves several functions. First, it moves the trapped air between layers. Second, it compacts the fiber layers for efficient force transmission among fiber bundles and prevents shifting of fiber orientation during cure. Third, it reduces humidity. Finally, and most important, the vacuum bagging technique optimizes the fiber-to-resin ratio in the composite part. These advantages have for years enabled aerospace and racing industries to maximize the physical properties of advanced composite materials such as carbon, aramid and epoxy.

2.3 Autoclave Curing

It refers to the curing of usually pre-peg composite materials or components under the controlled parameters vacuum, temperature, pressure and time. Autoclave molding is a modification of pressure-bag and vacuum-bag molding.

This advanced composite process produces denser, void free moldings because higher heat and pressure are used for curing. It is widely used in the aerospace industry to fabricate high strength/weight ratio parts from preimpregnated high strength fibers for aircraft, spacecraft and missiles. Autoclaves are essentially heated pressure vessels usually equipped with vacuum systems into which the bagged lay-up on the mold is taken for the cure cycle. Curing pressures are generally in the range of 50 to 100 psi and cure cycles normally involve many hours.

2.4 Trimming

When machining complex structures, such as those found in aerospace manufacturing, the cost of each structure prior to machining is extremely high. Mistakes are not an option as the lead time to get to the machining stage is usually so long that any mistakes completely wreck the delivery of the entire project or product, not just the one part. CNC machine simulation delivers defect-free NC programs more quickly to the workshop.

2.5 Testing

The mechanical testing of composite structures to obtain parameters such as strength and stiffness is a time consuming and often difficult process. It is an essential process, and Can be somewhat simplified by the testing of simple structures, such as flat coupons. The data Obtained from these tests can then be directly related with varying degrees of simplicity and Accuracy to any structural shape.

3. Inspection – Non-destructive Testing

3.1 C-Scan

C-scan gives two-dimensional data presentation. It gives plan view of defects in a color Printout i.e. length and breadth of defect. It is based on ultrasonic principle.Many computerized ultrasonic C-scan systems have appeared recently for inspection of aircraft structures. The principal advantage of a computerized system is that raw data from the test can be stored on disc and recalled at different sensitivity levels in the video image. For conventional C-scan in hard –copy , the structure would have to be re – scanned if the test sensitivity had to be altered, a task which could take several hours. The C-scan is nothing but an attenuation map of the structure. In a video image, each pixel color represents an amplitude level in the monitor echo or through –transmission pulse. The color scale is carefully selected to prevent essential information being lost.

For large structures, each pixel may represent thirty or forty data points from the scan. The pixel color may represent a mean amplitude value, or for attenuation mapping the minimum amplitude valve or when an echo from a bond like is been monitored the maximum amplitude value of responses from the bond.

If the computer prints hard copies of two isometric projections with only a slight displacement in the grid axis, they can be viewed as stereographic pairsIn summary the digital processing of ultrasonic C-scan data is making a considerable contribution to the testing of structures in advanced composites.

4. Destructive Testing

4.1 Inter Laminar Shear Strength (ILSS)

This is a bending test carried on a short specimen designed such that breaking occurs under the effective of the shearing load and not according to the normal stresses. This test is normally carried out for min-incoming inspection, process check & life extension of prepregs. This test provides information on the mechanics behavior of the resin or the fiber resin liaison. The figure 4.1 shows a composite experiencing a shear load. This load is trying to slide adjacent layers of fibers over each other. Under shear loads the resin plays the major role, transferring the stresses across the composite. For the composite to perform well under shear loads the resin element must not only exhibit good mechanical properties but must also have high adhesion to the reinforcement fiber. The interlinear shear strength (ILSS) of a composite is often used to indicate this property in a multiplayer composite (‗laminate‘).

The laminates are made up of Carbon(C), Carbon – Kevlar (CK) and Carbon - Kevlar – Glass (CKG) laminates. By using the shear load and various orientations, the average Inter Laminar Shear Strength is calculated. The percentage of variation for every laminate sample coupons is taken into consideration. The Correction Factor ‗β‘ is calculated. The correction factor is calculated so as to find out the other values of orientation easily by multiplying the correction factor with the other values.

LAMINATE	ORIENTATION	AVERAGE ILSS
C-1	0/90	71.76
C-2	0/45	71.50
C-3	45/90	76.05
C-4	0/90/45	74.11
C-5	0/45/90	74.89
C-6	45/90/0	76.20

Table 4.1

LAMINATE	ORIENTATION	AVERAGE ILSS
CG-1	0/90	71.69
CG-2	0/45	74.38
CG-3	45/90	68.81
CG-4	0/90/45	76.50
CG-5	0/45/90	72.91
CG-6	45/90/0	72.33

Table 4.2

LAMINATE	ORIENTATION	AVERAGE ILSS
CKG-1	0/90	46.74
CKG-2	0/45	48. 63
CKG-3	45/90	42.63
CKG-4	0/90/45	44.43
CKG-5	0/45/90	43.02
CKG-6	45/90/0	42.60

Table 4.3

4.2 Flexural Strength

The resistance of a material to breakage by bending stresses. The strength of a material in bending expressed as the tensile stress of the outermost fibers of a bent test sample at the instant of failure. Flexural loads are really a combination of tensile, compression and shear loads. When loaded as shown (Figure 4.2) the upper face is put into compression. The lower face into tension and the central portion of the laminate experiences shear.. The flexural strength test employs rectangular bar specimens submitted to three- or four-point bending, producing tensile stresses on the lower surface of the specimen and compressive stresses on the upper surface, where load is applied. By performing the Flexural Strength Test, percent of variation and correction factor 'β' is calculated.

Flexural strength and stiffness are not basic material properties. They are the combined effects of a material's basic tensile, compressive and shear properties. That is, when a flexural loading is applied to a specimen, all three of the material's basic stress states are induced. Material failure, then, is dictated by which of the three basic stresses is the first to reach its limiting value — that is, its strength. Despite the obvious complexities implied by the above, flexural testing is common, the test specimen is easy to prepare, the fixture can be simple and the test itself is easy to perform.

LAMINATE	ORIENTATION	FLEX STRENGTH
C-1	0/90	854.59
C-2	0/45	625.66
C-3	45/90	639.29
C-4	0/90/45	734.21
C-5	0/45/90	726.45
C-6	45/90/0	721.96

Table 4.4

Typically, all three or four loading/support points lie in the same horizontal plane. Thus, if the specimen has any twist along its length, or has top and bottom surfaces that are otherwise not flat and parallel to each other, it will not rest uniformly on the contact surfaces. For flexible materials, this is not a significant problem because as soon as the load is applied, the specimen readily conforms to the supports, and in doing so, induces minimal extraneous stresses.

LAMINATES	ORIENTATION	FLEX STRENGTH
CG-1	0/90	622.44
CG-2	0/45	574.05
CG-3	45/90	566.30
CG-4	0/90/45	618.19
CG-5	0/45/90	744.87
CG-6	45/90/0	606.40

Table 4.5

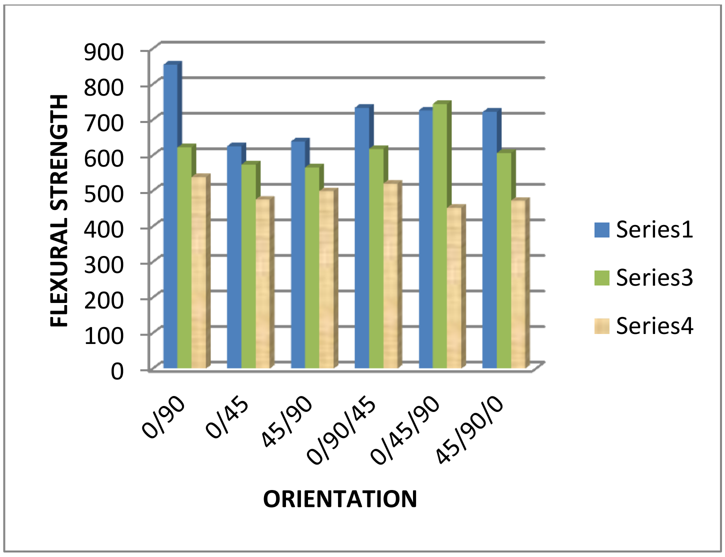
LAMINATES	ORIENTATION	FLEX STRENGTH
CKG-1	0/90	538.88
CKG-2	0/45	475.41
CKG-3	45/90	499.53
CKG-4	0/90/45	520.47
CKG-5	0/45/90	452.57
CKG-6	45/90/0	472.42

Table 4.6

5. Results

Shear Stress plays a vital role. Where maximum of 45° orientation is present the strength is higher. It is inferred that ILSS varies with different materials at different orientation. The correction factor β is calculated. The comparison graph for Carbon, Carbon – Glass, Carbon – Kevlar – Glass is plotted and studied.

This Experimental work will be a base line for calculating the actual strength based on test coupon results for the components fabricated with different orientations.This data will help designers and manufacturers to fabricate better quality components.



Graph 5.1

The following graph illustrates that 45° consists of maximum strength.

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