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Effect of Fibre Orientation on Flexural Properties of Carbon Fibre Reinforced Epoxy (CFR-E) Composite Material

[#1]Kishor Shingare, [#2]Prof. P.V. Deshmukh

[1]kishorshingare911@gmail.com
[2]pvdeshmukh@aissmscoe.com

[#1]P.G. Student, Mechanical Engineering Department, Savitribai Phule Pune University, AISSMS, College Of Engineering, Pune 01

[#2]Asst. Professor, Mechanical Engineering Department, Savitribai Phule Pune University, AISSMS, College Of Engineering, Pune 01

ABSTRACT

This paper investigates the effect of fibre orientation on the flexural strength of fibre reinforced –epoxy laminated composite material, with the variation in the orientation ($0^0/90^0$ and $0^0/-45^0/45^0/90^0$) of the reinforced fibre. There will be a substantial variation in the flexural strength of the laminated composites. In the present paper fabrication of carbon fibre reinforced laminated composites with varying orientation of reinforced fibre were prepared using the hand layup and these specimens are subjected to 3 point static bending testing the investigations are carried out as per the ASTM D790 standards. Using the load - deflection graph the maximum load, flexural Strength of the specimen for different laminated composites is evaluated and the appropriate conclusions are drawn.

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I. INTRODUCTION

Composite materials are produced by combining two dissimilar materials into a new material that may be better suited for a particular application than either of the original material alone. Many of our modern technologies require materials with unusual combination of properties that cannot be met by the conventional materials. This is very true for materials that are needed for the aerospace, marine and automotive application. Many composite materials are composed of just two phases one is termed the matrix, which is continuously surrounded by the other phase, often called the dispersed phase. Fibre reinforced composites are extensively used in present day technology because of its extensive benefits, Technologically the most important composites are those in which the dispersed phase is in the form of a fibre. Design goal of fibre reinforced polymer often include high strength and /or stiffness on a weight basis.Fibre reinforced composites with exceptionally high specific strengths and moduli have been produced that utilize low density fibre and matrix materials. Composite laminates offer alternative material design solutions in terms of specific strength and stiffness allowing important weight savings. Polymer composites also offer significant freedom to the designer by allowing, optimizing the strength and stiffness of a component or structure for a particular application.Recently an increasing use of composites reinforced with different types of fibre has occurred, owing the following advantages: they are strong enough, light in weight, abundant, non-abrasive and cheap. It is well known that the mechanical properties of polymer composites such as strength and modulus are obtained from the combination of the use of the filler (reinforcing material) and the matrix material properties and the ability to transfer the stress across the fibre matrix interface. Unidirectional fibre–reinforced laminated polymers exhibit outstanding specific stiffness and strength along the fibre direction. This has resulted in a wide range of application as structural materials. However matrix and fibre behaviour follows iso-strain approximation until the onset of failure, it was possible to predict the tensile and compressive strength in the fibre direction.Composites are rarely used in the form of unidirectional laminates, since one of their great merits is that the fibres can be arranged so as to give specific properties in any desired direction. Thus, in any given structural laminate, predetermined proportions of the unidirectional plies will be arranged at some specific angle, θ, to the stress direction. In order to calculate the properties of such a multi-ply laminate, it is first necessary to know how the elastic response of a single unidirectional lamina, will vary as the angle to the stress direction is changed. This Paper gives the introduction about the fibre and fibre orientation and its influence

II. MATERIALS & METHODS

A. Laminate Fabrication

- Selection of Composite material –
- Reinforcement - Carbon (200 GSM).
- Matrix – Epoxy Epolam Resin & Hardner 5015.

Properties of materials used are tabulated are as follows:

TABLE 1
MATERIAL PROPERTIES (SI UNIT)

Material	Properties	Value
Carbon Fiber	E_f	242
	ρ_f	1.81
	v_f	0.25
Epoxy Resin	E_m	3.7
	ρ_m	1.14
	v_m	0.245
Laminate (Orthotropic)	E_1	134.766
	$E_2=E_3$	8.071
	ρ_C	1.62
	$G_{12}=G_{13}$	3.412
	G_{23}	3.104
	v_{12}	0.25
	V_f	0.55

B. Fabrication of Carbon Fiber Laminate

The reinforcing material such as Unidirectional 200 GSM Carbon fibres are cut into required size and are laid on the flat surface of the mould. The fibres of the required size are laid along the required direction as per the design requirements. The resin and hardener of EPOLAM are mixed in the proportions as recommended by the manufacturer in the required proportions that is in the proportions of 70:30 as suggested by the manufacturer is mixed thoroughly and is applied on the laminated surface to be laminated. First put ply of carbon fibre in 0^0orientation.The resin is spread evenly on the reinforcing fiber, the resin is squeezed evenly on the surface using a roller and compressed thoroughly with the roller itself. Then put another ply in 90^0orientation. Also follow same procedure for Quasi-isotropic (0^0/-45^0/45^0/90^0) orientation. The reinforcing fibres are stacked one above the other and the above mentioned procedure is repeated up to 8 layer of carbon fiber. Then prepared laminate is placed under heavy load for 24 hours in room temperature. From this plate of approximate 3mm thickness is obtained. The laminate is ready and this laminate is cut into required size as per ASTM D790 standard i.e. span to thickness ratio is 16:1.Details of the composite specimens fabricated are as shown in Fig 2 below.

The 3-point bending tests were performed in a servo controlled UTM machine according to the procedure outlined in ASTM D790. Number of specimens was tested for each thickness of laminate. The tested specimens were examined through visual inspection for failure of fibers and matrix.

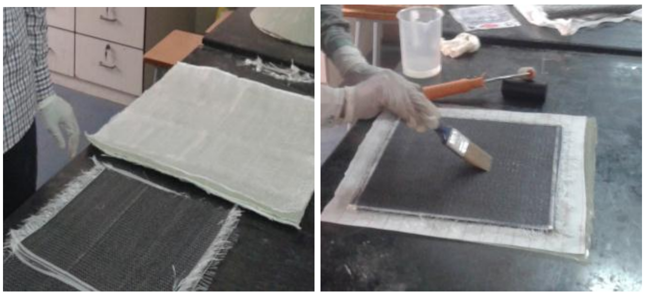

Fig.1. Preparation of specimen using Hand Lay-up.

Fig.2. Flexural specimen.

C. Definition: Flexural Strength

The maximum stress at the outer surface of a flexure test specimen corresponding to the peak applied force prior to flexural failure. The flexural strength is the ability to resist deformation under load for a material. The material deforms significantly but does not break, the load at yield is typically measured at 5% deformation/strain of the outer surface, is reported as the flexural strength or flexural yield strength. The test beam specimen is under compressive stress at the concave (inner) surface and tensile stress (Outer) at the convex surface. ASTM D790 test gives the procedure to measure a material's flexural modulus. The flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material’s stiffness when flexed.

III.TEST PROCEDURE

The specimen with the given span is supported between two supports as a simply supported beam and the load is applied at the centre by the loading nose producing three point bending at a specified rate by using UTM. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM

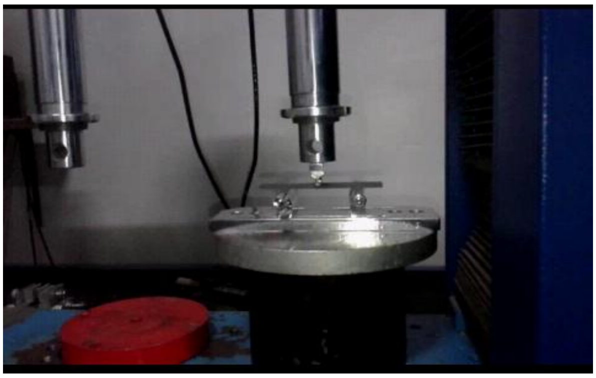

Fig.3. Specimen Loaded on UTM

The composite laminates were subjected to various loads and computer controlled UTM. The specimens were clamped and tests were performed. The tests were closely monitored and conducted at room temperature. The load at which the complete fracture of the specimen occurred has been accepted as breakage load. Fig.3 shows loading diagram of three point bending test.

By taking the values of max. load and slope from graphs we have obtained we can calculate flexural strength and flexural Modulus of beam with help of following formulae.

1. Max. Flexural Stress (3 Point Bending)

$$= \sigma = \frac{3PL}{2bh^2}$$

IV. RESULTS AND DISCUSSION

A. Graphical Results

GRAPH 1: LOAD VS DEFORMATION (8 LAYER BEAM)

GRAPH 2: LOAD VS DEFORMATION (8 LAYER BEAM)

From the graph 1 and 2 Curves for specimens with ($0^0/90^0$ & $0^0/-45^0/45^0/90^0$) shows linear behavior until failure. It is observed that as thickness is increased the load carrying capacity is also increased. At the peak load deformation is also increased with respect to 8 layer specimen. As the result, the flexural strength is also increased as thickness increases, and the deformation is increased as the load increases with respect to thickness.

B. Experimental Results

We have done testing i.e. experiment on UTM machine for Three Point Bending. From this we get results of max. load that we have applied on specimen at which rupture occurs or fails. Also we get deformation of beam after loading. All these results are tabulated as follows:

TABLE II (SI UNIT)
Results of Flexural Testing with ($0^0/90^0$) orientation

Layer	C.F	Thk(mm)	Width(mm)	Load(N)	Strength(MPa)
8	C.F.1	2.8	12.7	692.07	473.3
	C.F.4	2.9	12.7	658.85	447.0
	C.F.5	3.0	13.0	707.65	484.0
Average					**468.1**

TABLE III (SI UNIT)
Results of Flexural Testing with ($0^0/-45^0/45^0/90^0$) orientation

Layer	C.F	Thk(mm)	Width(mm)	Load(N)	Strength(MPa)
8	C.F.1	2.7	12.7	554.6	449.3
	C.F.4	2.7	12.8	628.1	504.9
	C.F.5	2.7	13.0	562.5	459.3
Average					**471.1**

V. CONCLUSION

Three point bending tests were carried out on specimens of $0^0/90^0$ and $0^0/45^0$ hand layup composites of carbon fibre reinforced laminates of 8 layered specimens.

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The findings of the present investigation are as follows.

- The flexural test (3 point bend test) provides a better understanding of the mechanical behaviour of the laminated composites.
- The type of fibre orientation plays a significant role in the determination of the flexural strength.
- The laminates with fibre orientation $0^0/45^0$ have exhibited more flexural strength than the laminates with $0^0/90^0$orientation for the same type of the fibre reinforcement.
- The fibres with $0^0/90^0$ orientation could carry more load than the fibres with $0^0/45^0$ orientation.
- For the same thickness of the specimen graphite fibres have exhibited better flexural strength.
- The visual inspection of (Graphs) the specimens reveals brittle failure of the specimens.

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