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Fibre Orientation and Its Influence on the Flexural Strength of Glass fibre and Graphite fibre reinforced polymer composites

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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 of the reinforced fibres there will be a substantial variation in the flexural strength of the laminated composites. In the present paper fabrication of glass fibre reinforced laminated composites and graphite fibre reinforced laminated composites with varying orientation of reinforced fibres were prepared using the hand layup, vacuum baggage technique and these specimens are subjected to 3 point static bending testing the investigations are carried out as per the ASTM standards. Using the load - deflection graph the maximum load, maximum deflection and the flexural strength of the specimen for different laminated composites is evaluated and the appropriate conclusions are drawn.

Key words: Laminated, fibre reinforced, flexural, orientation, stiffness, strength, glass fibre, graphite fibre.

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 [1]. This is very true for materials that are needed for the aerospace, underwater 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 [2]. 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. Furthermore, thermoplastic resins present increased interest due to their economic and mechanical advantages, such as easy fabrication, unlimited shelf life, intrinsic recyclability, high toughness and increased moisture resistance. Recently an increasing use of composites reinforced with different types of fibres has occurred, owing the following advantages: they are strong enough, light in weight, abundant, non-abrasive and cheap [3]. 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. These properties, however, are affected by a number of parameters like concentration of the filler, geometrical size and shape of the filler, filler aspect ratio, and the degree of interfacial adhesion between the filler and the matrix [4]. 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 [5]. The damage tolerance of polymeric materials can be enhanced by improving the inter laminar properties of the polymer composites [6]. In recent years, micro- and nano-scaled particles have been considered as filler material for epoxy to produce high performance composites with enhanced properties [7]. modified unidirectional car-bon/epoxy by using very thin alumina platelets. It is observed that a 39 % enhancement in flexural strength by infusing 1.5 wt% SiC nano particles in carbon/epoxy composite.

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.

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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 is organised as follows: Section I give the introduction about the fibre and fibre orientation and its influence, further it deals with the various earlier work carried in this regard. Section II deals with the detailed methodology used in manufacturing the fibre reinforced composite with different fibre reinforcement. Section III enumerates in detail the experimentation of various experiments carried. Section IV deals with the results and discussion and section V concludes the paper and followed by the various references.

II. MATERIALS AND EXPERIMENTATION

The fabrication of fibre reinforced laminated composite laminate was carried out through vacuum bag moulding technique, the reinforcement of hand- lay –up was applied to the bi-woven glass and graphite fibres, the vacuum bag technique is used to eliminate the entrapped air and excess resign in the mould. The laminated composite specimens were fabricated as per standard procedure and are tested. The fibres chosen were bi-woven glass fibre with density of 200gsm and graphite fibre with density 200gsm, the bi-woven glass fibres of $0/90^0$ and $0/45^0$ of glass fibres and graphite fibres of 0.3 mm thickness were stacked along the predetermined orientation and laminates of 2mm thick and 4mm thick were built the bonding of the glass fibre and graphite fibre cloth is using an adhesive made from a mixture of **LY556** resin & **HY 951** hardener in proportions of 100:10 by weight. The surfaces are thoroughly cleaned in order to ensure that they were free from oil, dirt. etc., before bonding at room temperature and pressure. The models will be allowed to cure for about 24 hours. Thicknesses of the Specimens were maintained at 2 mm & 4 mm throughout the experiments for all the specimens prepared. Details of the composite specimens fabricated are as shown in Fig 1 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 crosshead speed was maintained at 2mm/min. The tested specimens were examined through visual inspection for failure of fibres and matrix. Densities of composite laminates were determined by the Archimedes principle to calculate the specific values (property/density) of flexural properties.

Fig. 1: Preparation of specimen using land layup

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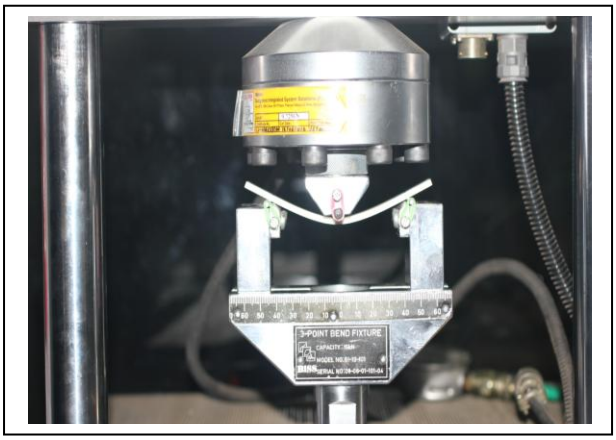


Fig.2:Picture Showing the Flexural Test Conducted on the test rig.

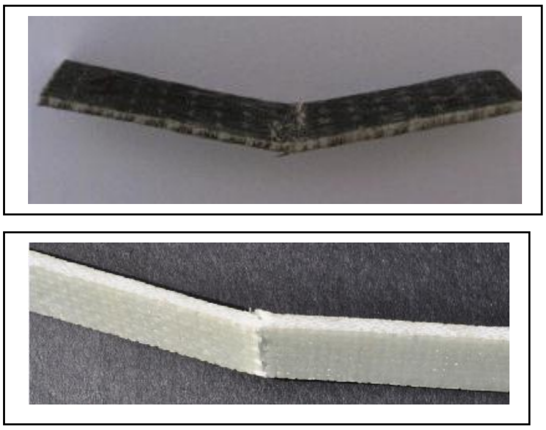
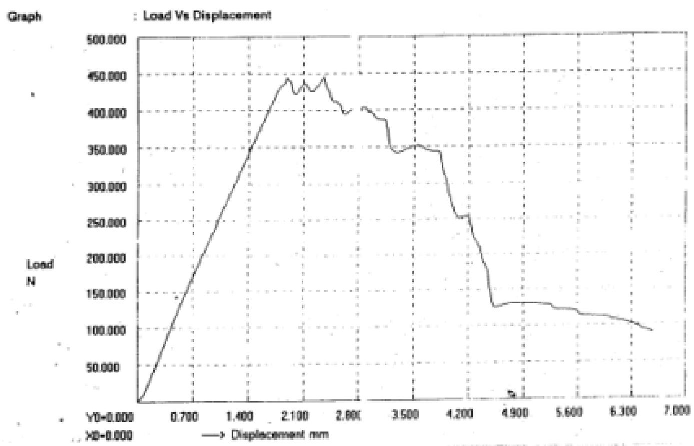
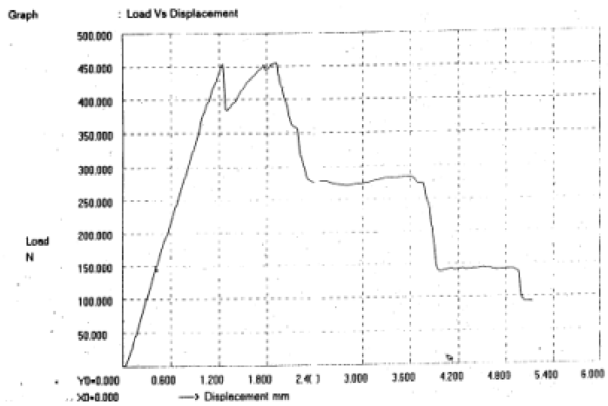


Fig 3: laminates after failure.

III. EXPERIMENTATION



Graph: 2mm Glass Fibre Laminate



Graph: 2mm Graphite Fibre Laminate

TABLE -I
Percentage of Fibre and Resin Content

Material	Fiber (%)	Resin (%)
Glass (FRP)	52	48
Graphite	54	46

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TABLE -II
Showing Load and Flexural Strength of Glass fibre reinforced and Graphite Fibre reinforced Composite laminate

No. of Trials	Specimen	Fiber orientation	Load N	Average Load N	Deflection mm	Average deflection mm	Flexural Strength Mpa	Average Flexural Strength MPa
Trial 1	Glass Fiber 2mm	$0/90^0$	427.00	468.00	2.49	2.88	253	281.5
Trial 2			468.00		2.60		279	
Trial 3			509.00		2.79		310	
Trial 1	Glass Fiber 2mm	$0/45^0$	445.25	430.93	2.36	2.13	421	409
Trial 2			418.75		1.78		389	
Trial 3			428.79		2.25		417	
Trial 1	Glass Fiber 4mm	$0/90^0$	610.50	611.37	2.70	2.83	211	218
Trial 2			611.37		2.83		218	
Trial 3			612.25		2.97		225	
Trial 1	Glass Fiber 4mm	$0/45^0$	561.75	593.58	4.87	4.63	310	324
Trial 2			539.75		4.69		293	
Trial 3			679.25		4.34		369	
Trial 1	Graphite Fiber 2mm	$0/90^0$	432.25	427.12	1.71	1.89	425	434
Trial 2			427.00		1.89		434	
Trial 3			422.0		2.07		443	
Trial 1	Graphite Fiber 2mm	$0/45^0$	455.25	468.37	1.92	1.94	465	465.5
Trial 2			468.00		1.95		465	
Trial 3			481.50		1.96		466	
Trial 1	Graphite Fiber 4mm	$0/90^0$	716.50	716.50	3.11	3.11	424	424
Trial 2			712.00		2.90		426	
Trial 3			721.00		3.10		422	
Trial 1	Graphite Fiber 4mm	$0/45^0$	664.50	688.62	3.24	3.09	390	405
Trial 2			668.00		3.05		404	
Trial 3			712.75		2.94		421	

TABLE-III
Indicates the maximum load, deflection and maximum flexural strength

Details	Glass composites				Graphite composites			
	2mm $0/90^0$	2mm $0/45^0$	4mm $0/90^0$	4mm $0/45^0$	2mm $0/90^0$	2mm $0/45^0$	4mm $0/90^0$	4mm $0/45^0$
Maximum Load at break (N)	468.00	430.93	611.37	593.58	427.12	468.37	716.50	688.62
Maximum Deflection, mm	2.88	2.13	2.83	4.63	1.89	1.94	3.11	3.09
Flexural Strength(N/mm^2)	281.5	409	218	324	434	465.5	424	405

IV. RESULTS AND DISCUSSION

The bi woven glass fibre reinforced laminated composites and bi woven graphite fibre reinforced laminated composites of 2mm and 4mm thickness with $0/90^0$ and $0/45^0$ orientation were manufactured as per the standard. These specimens were cut to the required shape and size as per the ASTM D790 test standards. The specimens were subjected to the flexural loading with gradual loading and were tested till failure. Simple digital flexural test system is utilized to determine the various flexural parameters and is tabulated in the above table. The graph of load versus deflection for different thickness specimen and different orientation are obtained, the curves shows linear behaviour until failure. The visual inspections show a brittle failure of the specimens. It can be noted from the graph that the flexural strength of laminates with $0/45^0$ orientation exhibited excellent flexural strength than that of the fibres with $o/90^0$ orientation. Further graphite fibre reinforced laminated composites with $0/45^0$ orientation have higher flexural strength than glass fibre laminated composites with the same fibre orientation.

V.CONCLUSION

Three point bending tests were carried out on specimens of $0/90^0$ and $0/45^0$ hand layup composites of glass fibre and graphite fibre reinforced laminates of 2mm and 4mm thickness.

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 $0/45^0$ have exhibited more flexural strength than the laminates with $0/90^0$ orientation for the same type of the fibre reinforcement.
- The fibres with $0/90^0$ orientation could carry more load than the fibres with $0/45^0$ orientation.
- For the same thickness of the specimen graphite fibres have exhibited better flexural strength.
- The visual inspection of the specimens reveals brittle failure of the specimens.
- Graphite fibre laminates with $0/45^0$ orientation have higher flexural strength than glass fibre laminated composites with the same orientation.

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