

## ***Investigation of Flexural Failure Modes in Laminated Composites: An Experimental Approach***

***RajanishM<sup>1</sup>, N.V. Nanjundaradhya<sup>2</sup>, Ramesh S Sharma<sup>3</sup>, VChayapathy<sup>4</sup>***

*Dept. of Mechanical Engineering<sup>1,2,3</sup>, Dept. of Electrical and Electronics Engineering<sup>4</sup>*

*RV College of Engg., Bangalore, India,*

*Corresponding Author: prof.m.rajanish@gmail.com*

### ***Abstract***

*The research and development of high performance structural materials for aerospace and automotive have long been focused on the weight saving and minimal environmental impact. Accordingly, lightweight characteristics in structural materials have become one of the basic requirements for all systems where these composite panels are subjected to bending load. Prediction of the flexural strength of a high performance laminated composite is important for engineering application yet difficult in nature. The purpose of this work is to analyze the flexural behaviour and progressive failure process of laminated composites subjected to a bending load. The analysis is based on the classical lamination theory. Only the mechanical properties of constituent fiber and matrix materials under the bending load condition and the laminate geometric parameters are required. All these data will be measured independently before composite fabrication. As one does not know a priori which ply failure corresponds to the ultimate failure, the use of only the stress failure criterion is no longer sufficient for the determination of the laminate ultimate strength.*

***Keywords:*** *Hybrid Composites, Matrix, Epoxy resins, Metal Matrix, Glass Fiber.*

### **1. INTRODUCTION**

A considerable volume of literature exists concerning the failure modes of composite

matrix composites. A composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface

between them. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. .

Thermal failure of SiC particulate- Reinforced Aluminum alloy composites induced by both laser thermal shock and mechanical load has been investigated by Y.C.Zhou [1]. Short fiber reinforced polypropylene hybrid composites were investigated to determine their mechanical properties in case of reinforcing fiber types by TiborCzigany [2]. M.J.Drews et.al

Investigated the fatigue failure modes of fiber/elastomer composites were observed and a new principal failure mechanism was used to design new materials with sufficient longevity for bearing applications [3]. La Berge et al. (1991) and Chow et al. (1994) have demonstrated that severe fatigue stress concentrations occur in an LME layer and at the attachment edge of the coating decreasing its fatigue strength [4].

M.R.Djazez et.al and his team have investigated the microstructure and strength of particulate metal matrix composites [5]. C.M.Friend in his paper has described the

effect of matrix alumina fiber-aluminum metal matrix composites [6]. Recent trends in advancement on metal matrix composites is provided in the reference no. [7]. J. Humphreys in his work on metal matrix composites has explained about the deformation and annealing mechanisms in discontinuously reinforced metal-matrix composites [8].

The mechanical interface aspects in metal matrix composites were studied by L.J.Ebert [9]. The load redistribution in a hybrid composite sheet due to fiber breakage and its stress concentration factor for both types of fibers immediately adjacent to a group of fractured fibers have been evaluated by H.Fakuda [10]. Tests have been conducted on single carbon fibers, bundles of 1000 carbon fibers impregnated with epoxy resin and on a glass/carbon hybrid composite containing similar bundles interspersed in glass/epoxy resin.

The influence of the bundle dispersion on the strength of the carbon bundles has been discussed and suggestions for the optimum dispersion were made by M J Pitkethly and M G Bader [11]. Biner S.B [12] investigated fracture behavior of a laminated composite of layers of metal matrix composite having 20% vol.

particulate SiC and 2014- aluminum matrix and 6061 aluminum as the ductile layers, under mixed mode loading. In this study tensile, notched beam 3-point bending and compact tension tests were conducted in order to study the hybrid effect on 3-d braided composites.

## 2. EXPERIMENTAL INVESTIGATIONS

Manufacture of Laminated Composites Bi-woven glass cloth & carbon laminate which is commercially available is used as fibers for making the specimens with epoxy

resin as matrix. The surfaces were thoroughly cleaned in order to ensure that they are free from oil and dirt before bonding at room temperature.

An adhesive made from a mixture of LY556 resin & HY 951 hardener mixed in the ratio of 100:10 by weight was then applied. Vacuum hand lay – up technique (Figure 3.1) was used to make the specimens. Vacuum level (500 mm of Mercury for 2 hours) was monitored so as to avoid surface undulations and also avoid air pockets at the interface.

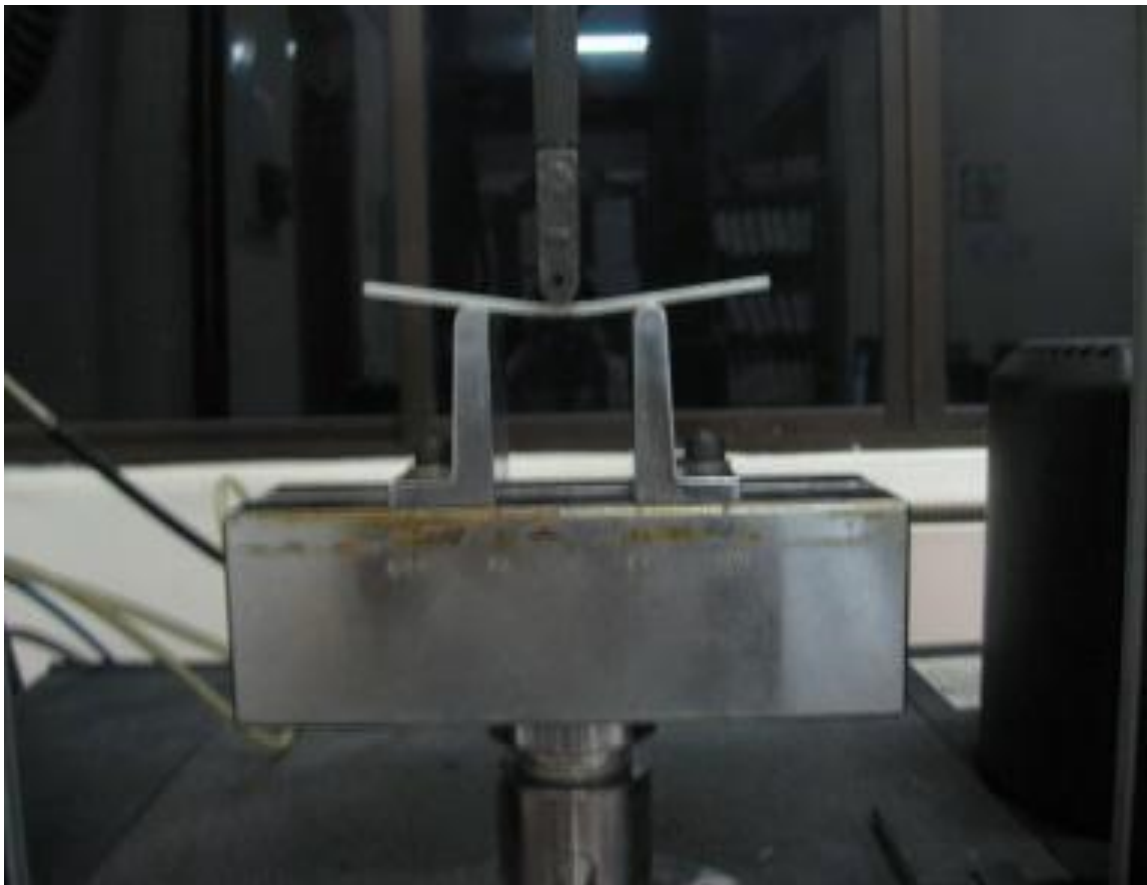


*Figure 1: Manufacture of Glass fiber laminate using Vacuum hand lay – up technique*

### **Testing of composite laminates**

Three point bend test were conducted as per ASTM D 790 were carried out to determine laminate bending stiffness and bending strength on both the types of composite panels. Three-point bend tests were conducted and the method of loading is indicated in Fig. 3.2.

Flexural testing with central loading has been carried out in accordance with ASTM D 790 using Flexural Testing Machine. The movable carriage of the machine is brought on the loading bar and load is applied gradually at the cross head displacement rate of 2 mm/min. Plot of load versus deflection is recorded.



*Figure 2: Flexural test specimen mounted in Digital Flexural Test System*

**Table 1: Specimen Designation**

Sl. No.	Specimen Details	Specimen Designation	Type of Test	No. of Specimens
1.	Biwoven glass cloth laminate – 2mm	FL - GFRP 2	BENDING	3
2.	Biwoven glass cloth laminate – 3mm	FL - GFRP 3	BENDING	3
3.	Biwoven Carbon cloth laminate – 2mm	FL - CFRP 3	BENDING	3

FL - GFRP 2 – Flexural Test on Glass Fiber Reinforced Plastic with 2 mm thick

FL - GFRP 3 – Flexural Test on Glass Fiber Reinforced Plastic with 3 mm thick

FL - CFRP 2 – Flexural Test on Carbon Fiber Reinforced Plastic with 2 mm thick

## RESULTS AND DISCUSSIONS

The flexural properties of the composite specimens have been calculated using the measured data of the Load vs. Deflection Curve. The data obtained from the independent tests from three point tests on the same specimen were used in the calculations. The deflections undergone by the specimen have been found to be large in the case of three-point load test. The flexural

stiffness of the specimen kept increasing steadily in case of carbon fiber specimens when compared to specimens with glass fiber inserts and also it is close to the theoretically estimated values.

The next step is to assess the failure mode for the selected specimen thickness with known mechanical properties of the fibers. Composite beams under static bending loads can fail in several modes: fiber cracking, matrix failure, debonding of layers, and interfacial failure between the layers. With FRP as Glass and Carbon the thickness ranging from 2 to 3mm and compression failure mode of the layers were observed during bending. All the specimens were tested up to failure load and the results recorded.

**Table 2: Results of Max Load, Displacement, and flexural strength**

No. of Trials	Specimen	Max. load, kN	Average Load, kN	Flexural Strength, MPa	Disp mm	Average Disp, mm
Trial 1	Glass Fiber 2mm	0.4	0.4	390.4	1.0	1.04
Trial 2		0.38			1.0	
Trial 3		0.42			1.12	
Trial 1	Glass Fiber 3 mm	0.58	0.57	542.6	3.25	3.28
Trial 2		0.56			3.2	
Trial 3		0.58			3.4	
Trial 1	Carbon Fiber 2mm	0.30	0.28	443.2	2.25	2.08
Trial 2		0.27			2.0	
Trial 3		0.28			2.0	

### 3. CONCLUSIONS

This chapter is devoted to significant conclusions drawn from different aspects of laminated Matrix Composite panels investigated in this work. Broadly these are as under:

- The fabrication of laminated Composite specimens with two different fibers viz bi-woven glass cloth and carbon with two different thicknesses has been successfully carried out as per ASTM

Standards.

- A complete literature survey has been thoroughly conducted in order to understand the mechanics of glass as well as carbon fibers under flexural loading.
- A simple and Digital Flexural Test System has been utilized to determine Flexural parameters such as Flexural Strength, deflection for variety of Composites panels.
- Physical and mechanical properties of

metal matrix composite specimens have been extracted from literature available as per the relevant ASTM standards. These are required for a detailed analysis of strength and failure modes of the composite panels.

- Flexural Strength of laminated Composites for both were tested and results tabulated for both the thicknesses of the specimen. as per tests recommended by ASTM standards. The values obtained have been analyzed from data obtained from available literature & an excellent agreement between test results has been observed.
- The influence of carbon fiber as reinforcement of little higher density on the static behavior of composite panels has been examined. Substantial increase (12%) in flexural strength can be obtained with the introduction of carbon fibers matrices without any
- Appreciable increase in weight of the Composite panel.
- Failures modes of the laminated Composite specimens with different thicknesses have been analyzed and breaking load corresponding to the Failure mode that can occur have been recorded and the load versus deflection plot is tabulated for each test. The influence of carbon fiber on the load

bearing ability of composite panels have been examined and it is found that increase in the permissible load is substantial with the introduction of these fibers.

#### **4. FUTURE SCOPE OF WORK**

In the above work, the flexural strength estimation was carried out on two different fibers but at the same time, this work can be extended to other fibers such as Kevlar, boron, aramid etc available in the market. In addition, out of plane bending can also be addressed in future. Four point and three point bend tests can be conducted simultaneously on the same specimen to evaluate the flexural parameters.

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