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EFFECT OF THICKNESS ON FLEXURAL PROPERTIES OF LAMINATED COMPOSITES

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Abstract

This paper examines the influence of thickness on flexural properties of laminated composites, many structures used in Automobile, Aerospace, Naval and other Transportation vehicle structural parts are subjected to various kinds of loads. These structures are further subjected to bending loads causing flexural stress in the structures. The purpose of this work is to experimentally analyze the progressive failure process of laminated composites subjected to flexural loads, Flexural loading causes stresses in the composites, which vary through the thickness. These flexural stresses are the maximum at the outer surfaces and zero in the middle at the neutral axis. The stress in an individual ply depends upon the stiffness of that ply and its distance from the laminate's neutral axis. By including, one or more extra components having relatively better elastic properties in the laminate can help in improving the flexural properties of the composite.

This paper investigates the influence of thickness on flexural properties of glass fiber-epoxy, Graphite fiber-Epoxy & Carbon fiber –epoxy laminated composite material. In the present study the composite laminate specimen's are prepared using the vacuum baggage technique and the specimen are subjected to 3 point bending load on a simply supported pins and the investigation is carried out as per the ASTM D790 standards. Flexural properties evaluated are flexural strength and stiffness of the composites system appropriate conclusions was drawn.

Keywords: Laminate, Flexural Strength, E-glass, Three point bending, Stiffness

I. Introduction:

Laminated composites are finding increasing applications in transportation vehicles, aerospace, marine and aviation industries. In the recent decades this is due to their excellent features, such as high strength to weight and stiffness to weight ratios. The mechanical property of the composite becomes complex with the addition of fibers. When subjected to compression, tension and flexure tests polymeric composites are susceptible to mechanical damages that can lead to interlayer delamination. Catastrophic failure of the component can occur due to the increase in the external load.

Li and Xian [1] showed that the incorporation of a moderate amount of carbon fibers into ultra-high-modulus polyethylene fibers reinforced composites greatly improved the compressive strength, flexural modulus. Vinson and Sierakowski [2] applied the above approach to develop “an advanced theory” to obtain strength and stiffness of laminated beams under flexural load. Rohchoon and Jang [3] studied the effect of stacking sequence on the flexural properties and flexural failure modes of aramid-UHMPE hybrid composites. The flexural strength depends upon the type of fibers at the compressive face and dispersion extent of the fibers. Zsolt R’ACZ [4] studied the analysis of the flexural strength of unidirectional composite carbon fiber composites and estimated the magnitude of size effect in carbon fiber composite and result revealed that specimen with lower span to thickness ratio exhibits a lower flexural strength. Lassila J and Vallittu P [5] investigated the influence of the position of fiber rich on the flexural properties of fiber-reinforced composite construction. They found that the specimens with FRC positioned on the compression side showed flexural strength of approximately 250 MPa. While FRC positioned on the tension side showed strength ranging from 500 -600 MPa. T.Waki and T.Nakamura[6] studied and compared the flexural strength of three types of glass fiber reinforced composite systems. They found that the BR-100(686 MPa) and Vectris(634 MPa) beams demonstrated significantly higher flexural strength than the fiber kor (567 MPa)beam and also found that (Estenia/BR-100) composite had a good mechanical strength for metal –free restorations. J.Kosoric, et.al [7] has carried out research using E-glass fiberglass and epoxy resin with catalyst addition as matrix for the composite material. The modal test was carried out for the measurement of flexural properties and modulus elasticity on flexural testing machine the analysis showed that the glass fiber reinforcing the laboratory composite resins have greater effect on the flexural strength than modulus of elasticity. Mechanical properties of monodirectional fiber reinforced composite have been extensively studied by Jones [8]; Nabi Abolfathi et al. [9] presented a numerical algorithm, which can efficiently determine the elastic properties of bidirectional fibrous composites based on micromechanics approach. Khashaba and Seif [10] investigated the mechanical behavior of woven FRP composites under tension, bending, and combined bending/tension loadings. Mauricio et al. [11] predicted the elastic behaviour of hybrid plain weave fabric composites with different materials and undulations in the warp and weft directions by formulating a 3D analytical micromechanical model. Pu Xue et al. [12] presented an integrated micro macro model for woven fabric composites subjected to combined tensile and large shear deformation.

From the above literature, it is evident that there is no single source of literature available on experimental evaluation of flexural properties of bi-woven composite laminates under varying thickness. Hence, in this work it is proposed to address the flexural behavior of composite laminates with varying thickness under flexural loading conditions.

II. Experimental Investigation

a) **Preparation of surface**

Bi woven glass fiber is used as reinforcement in the form of bi directional fabric and epoxy resin as matrix for the composite material of the laminates specimens. Hand layup process is used to prepare the specimens. Surface of the mould is thoroughly cleaned by removing any dust and dirt from the mould. After the mould surface has been cleaned, the release agent is applied, where the mould surface is coated with silicon wax using a smooth cloth then the thin film of polyvinyl alcohol is applied over the wax surface using sponge. The matrix material used here is epoxy resin which is applies to create bonding between the layers of sheet in the ratio of 100:1.

b) **Preparation of the Laminate**

The first layer of Bi-woven glass fiber cloth (ranging from 0.25 mm to 0.35 mm) is laid and resin is spread uniformly over the cloth by means of brush shown in fig 1.1. The second layer of the cloth is laid and resin is spread uniformly over the cloth by means of brush. After second layer, to enhance wetting and impregnation, a teethed steel roller is used to roll over the fabric before applying resin. Also resin is tapped and dabbed with spatula before spreading resin over fabric layer. This process is repeated till all the 10 layers (2 mm thickness) and 16 layers (4 mm thickness) are placed. No external pressure is applied while casting and curing because uncured matrix material can squeeze out under high pressure. This results in surface waviness (non-uniformed thickness) in the model material. The casting is cured at oven temperature of about 100º C up to 2 hrs & finally removed from the mould to get a fine finished composite plate as shown in the fig 1.2 below

Fig 1.1 Bi woven glass cloth

Fig 1.2 Laminate under curing

c) **Preparation of test specimens:**

After the cure process, the test specimens are cut from the sheet to the following size as per ASTM standards (Flexural Specimen Dimensions as per ASTM D – 790) by using diamond impregnated wheel, cooled by running water. All the specimens are finished by abrading the edges on a fine carborundum paper as shown in the Fig 1.3.

Fig1.3 Flexural specimen.

d) **Testing Machine**

The universal testing machine used in the above test was manufactured by LLOYD INSTRUMENTS, U.K. It is a versatile and comprehensive testing machine which can be used as a standalone machine or it can be linked to a remote computer and data analysis software. This machine is designated as ‘LLOYD LR 50K’ and is shown in Fig 1.4. Tensile, compressive and flexural tests can be performed on this machine.

Fig 1.4 Universal Test Equipment

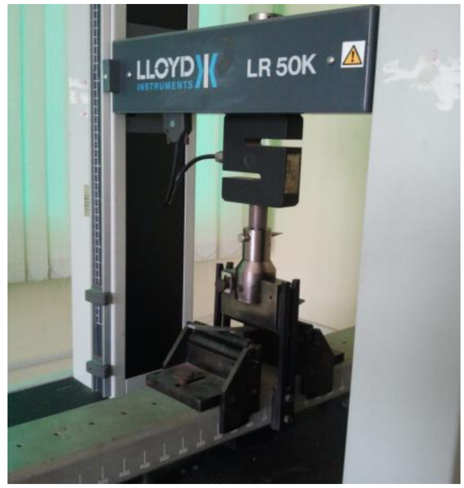

Fig 1.5 Specimen mounted.

The specimen is marked into 4 equal parts as shown in the fig 1.3 and is placed on the supporting pins; ensure that the loading pin should act exactly at the center of the specimen. The maximum load applied is 30 KN and the speed of the test is maintained at 3mm/min. Load is gradually applied on the flexural specimen and corresponding graph of Load vs. Deflection is obtained. Loading takes place until failure of the concerned specimen between the grippers. The above process is repeated for all the flexural specimens with different load until failure.

Table 1 - Specimen Designation and Measured Dimensions

Sl. No.	Specimen Designation	length (mm)	Width (mm)	Thickness (mm)
1	CAF/02/01	200.1	12.05	2.10
2	CAF/02/02	200.0	12.02	2.20
3	CAF/04/01	201.0	12.00	4.01
4	CAF/04/02	200.0	12.04	4.05
5	GR/02/01	200.3	12.01	2.20
6	GR/02/02	200.5	12.09	2.10
7	GR/04/01	201.0	12.10	4.06
8	GR/04/02	200.4	12.08	4.03
9	GLF/02/01	201.2	12.05	2.20
10	GLF/02/02	200.0	12.08	2.10
11	GLF/04/01	200.1	12.06	4.30
12	GLF/04/02	200.0	12.00	4.10

Table 2: Specimen designation

Sl. No.	Specimen Designation	Description
1	CAF/02/01	Carbon Fiber /2 mm thickness/Sample 01
2	CAF/02/02	Carbon Fiber/2 mm thickness/Sample 02
3	CAF/04/01	Carbon Fiber/4 mm thickness/Sample 01
4	CAF/04/02	Carbon Fiber/4 mm thickness/Sample 02
5	GR/02/01	Graphite Fiber/2 mm thickness/Sample 01
6	GR/02/02	Graphite fiber/2 mm thickness/Sample 02
7	GR/04/01	Graphite Fiber/4 mm thickness/Sample 01
8	GR/04/02	Graphite Fiber/4 mm thickness/Sample 02
9	GLF/02/01	Glass Fiber/2 mm thickness/Sample 01
10	GLF/02/02	Glass Fiber/2 mm thickness/Sample 02
11	GLF/04/01	Glass Fiber/4 mm thickness/Sample 01
12	GLF/04/02	Glass Fiber/4 mm thickness/Sample 02

III.Results

Table 3- Flexural Properties Glass, Carbon and Graphite composites with 2mm & 4mm thickness.

Sl. No.	Specimen	Max. Load (N)	Deflection at max load (mm)	Flexural Modulus (MPa)	Flexural Strength (MPa)
1.	CAF/02/01	772.0	11.78	46.43	213.1
2.	CAF/02/02	767.6	11.12	47.47	205.3
3.	CAF/04/01	974.9	6.56	50.95	117.0
4.	CAF/04/02	933.3	6.35	50.73	112.0
5.	GR/02/01	105.3	14.94	11.79	131.6
6.	GR/02/02	104.9	15.31	11.54	131.2
7.	GR/04/01	317.0	10.88	28.10	99.0
8.	GR/04/02	615.9	10.29	28.81	95.4
9.	GLF/02/01	93.22	10.81	15.95	116.5
10.	GLF/02/02	115.4	10.38	14.44	114.3
11.	GLF/04/01	263.3	8.26	45.91	82.3
12.	GLF/04/02	234.5	8.12	42.19	83.2

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Graphs:

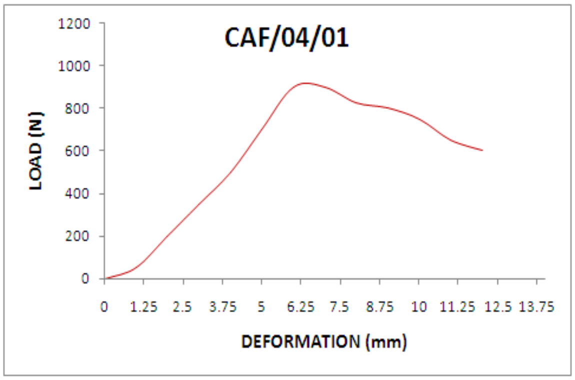

Fig 1.6 Carbon fiber 4 mm thick

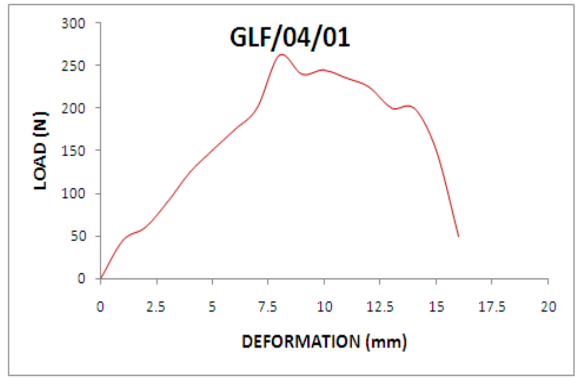

Fig 1.7 Glass fiber 4 mm thick

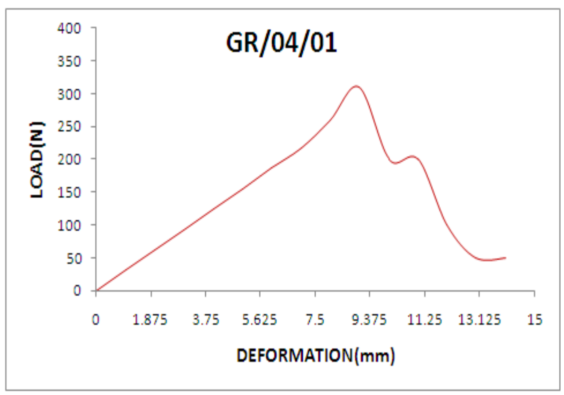

Fig 1.8 Graphite fiber 4 mm thick

Discussions

The results obtained from experimental work on the flexural testing of different fibers of laminated composites are illustrated in Table-3 which represents deflection of beam, flexural stress, flexural modulus and maximum flexural load. Results are obtained for two different thicknesses of 2mm & 4mm respectively. The results show that there is a variation of deflection and stresses from linear to nonlinear analysis beyond certain load. The values of deflection decreases as the thickness FRP laminated composite plate increase because of increase in stiffness of the plate. Similar trend is observed in the bending stress values indicated in table 3. Also, it is clear from the table 3 that the maximum value of the flexural strength (213.1 MPa) for Carbon and, while the minimum value of flexural strength (82.3 MPa.) for Glass fiber.

IV. Conclusions

The main conclusions of the experimental investigation of flexural analysis of laminated composite material are as follows:

- Flexural properties of Epoxy Glass, Graphite and Carbon Laminates of two different thicknesses were successfully conducted and results are recorded.
- The effect of specimen thickness on the flexural properties were evaluated and it is found that the slight increase in thickness increases the flexural properties such as flexural strength, modulus etc.
- The maximum value of deflection (15.31 mm) is at Graphite fiber, while the minimum value of deflection (6.35 mm) is at Carbon fiber.

Thus, it can be concluded that for same thickness and orientation, carbon fiber provides better flexural properties as compared to glass and graphite under flexural loading conditions.

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