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Comparative Study of Mechanical Characteristic for Symmetric and Asymmetric Glass Fiber Reinforced Polymer (GFRP) Laminate

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Abstract—*Glass fiber reinforced polymer woven laminates are well known for its excellent mechanical properties like high strength, flexibility, stiffness. This paper is a comparative investigation of bending strength and inter laminar shear strength (ILSS). Two different layup have been selected for relative study (i) Symmetric and (ii) Asymmetric laminate. A generalized layup sequence of fabricated 6 layer laminates for asymmetric laminate is [(0,90)/(+30,-30)/(+45/-45)//(0,90)/(+30,-30)/(+45/-45)] and symmetric laminate is [(0,90)/(+30/-30)/(+45/-45)//(+45,-45)/(+30/-30)/(0/90)]. Epoxy and hardener were mixed in 10:1.5 ratio in for this research work. Laminates were prepared by using hand layup method assisted by vacuum bagging technique at 1 atmospheric pressure. Three-point bend test and ILSS test proved that symmetric laminate having 20.46% high bending strength and 48.37% high shear strength as compared to asymmetric laminate.*

1. INTRODUCTION

There are different manufacturing techniques available for composite material manufacturing as: Vacuum-assisted resin transfer molding (VARTM), prepreg methods, pultrusion, filament winding, etc. Once laminate is ready mechanical testing can be done on materials, tensile testing, compression test etc. for FRP laminates has been studied by so many researchers. But daily increasing test facilities and new analysis tools availability, there are lots of possibilities to manufacture best composite (effective design) thus it is one of the best area of research.

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called reinforcing phase and one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibres particles or flake. The matrix phase materials are generally continuous [1-2].

In recent years, the fibre reinforced polymer (FRP) composites are now finding suitable materials for various application in automobile, building, electrical, and packaging sectors because of their several practical advantages like ease of processing, fast production cycling, and low processing cost over traditional materials[3]. One of the major scientific challenges for the composite engineers is the development of new stronger and tougher light weight structural materials supporting latest technologies and design concepts for the complex shaped structures like aircraft, automotive structures, and large wind turbine blade structures [4]. Fibre reinforced plastic (FRP) laminates have high in-plane strength and stiffness due to fibre reinforcement. Composite materials become more and more appealing for structural applications due to their light weight and excellent mechanical performances.

The inter-laminar shear strength (ILSS) is one of the most important parameters in determining the ability of a composite to resist delamination damage. Standardized test methods are the three point-bending tests according to ASTM D2344 for apparent Inter-laminar Shear Strength of Parallel Fibre Composites by Short-Beam-Shear (SBS). During bending in SBS, the load increases proportionally with deformation, until a peak load is reached. If the load drop by 30% or more immediately after the peak load is reached, it is assumed that the specimen failed in lamina shear and the peak load is then used to determine the apparent ILSS. The main advantage of the SBS is its simplicity. The specimens are relatively easy to prepare and the test itself is simple to conduct and requires little fixturing.

However, the SBS gives an accurate measure of ILSS value only if pure inter laminar shear failure takes place [5-6]. In this study, glass fibre reinforced polymer composite having symmetric and asymmetric 6-layer layup laminates have been considered.

2. EXPERIMENT

Glass fibre reinforced laminates polymers prepared by using hand layup method assisted by vacuum bagging technique at 1 atmospheric pressure.

2.1. Materials

Glass fibres reinforced epoxy matrix composite having symmetric and asymmetric composite are compared with various properties under Inter laminar shear strength test (ILSS) and three point bend test.

This composite has 6 layers of glass fibre lamina. The lamina in a composite laminate can be laid up in different orientations based on the properties required.

Three orientations of bidirectional glass woven were used for making symmetric and asymmetric laminate:

1. Plain woven glass fabric with warp and weft in 0˚and 90˚ direction — (0, 90).
2. Plain woven glass fabric with warp and weft in +45˚and -45˚ direction — (+45, -45).
3. Plain woven glass fabric with warp and weft in +30˚and -30˚ direction — (+30, -30).

The optimum ply orientation for the asymmetric laminate is [(0,90)/(+30,-30)/(+45/-45)//(0,90)/(+30,-30)/(+45/-45)] and symmetric laminate is [(0,90)/(+30/-30)/(+45/-45)//(+45,-45)/(+30/-30)/(0/90)] as shown in Fig. 1.

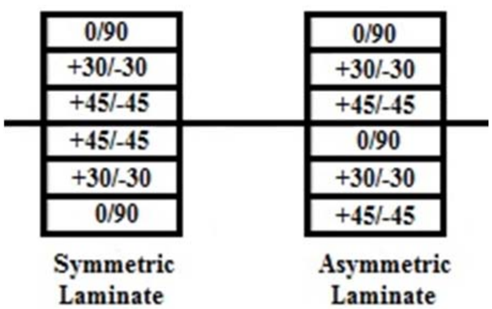

Fig. 1: Configuration of symmetric and asymmetric laminates.

The materials used in the manufacturing are listed in the Table 1:-

Table 1: Materials Used

Constituent	Specification
Glass Fiber	E-Glass 12000Tex
Epoxy	LY 556
Hardener	5200

2.2 Process used to prepare 6-layer GFRP

GFRP Laminates prepared by using hand layup method assisted by vacuum bagging technique at 1 atmospheric pressure. Hand layup process is manual process and it is labor intensive process. Glass fiber woven was cut in different ply orientation. Epoxy and hardener were mixed in proper proportion (10:1.5) and mixed for 15 minutes using hand mixer. Then ply with proper orientation were put on each other and resins applied in between layers. For extra resins iron roll with constant pressure used to squeeze it out. Once the layup is ready, this layup kept inside vacuum bas and vacuum using vacuum pump pressure of 1 atm achieved. High pressure was applied for 1 hour and then heavy loads were applied and layup was left for curing (24 hours).

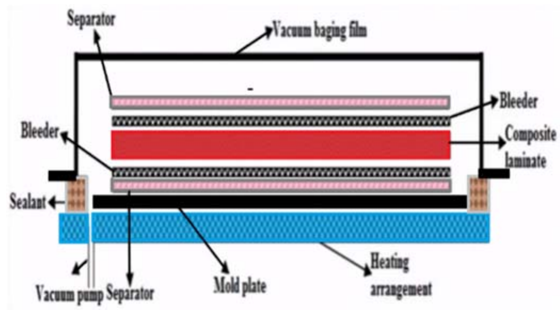

Fig. 2: Vacuum bagging process

2.3. Specimen Preparation

E-glass Fiber woven roving was used as fiber reinforcement. Epoxy resin with specifications mentioned in Table 1 was used as the matrix material. The composite lamina was prepared using the hand layup assisted by vacuum bagging method.

Thickness of glass fiber symmetric and asymmetric reinforced laminate was 3.0 mm and these laminate was cut in to pieces of 30 X 8 mm, sample preparation for ILSS and for three point bend test 46 X 20 mm, as shown in table 2 and 3.

Table 2: Specimen dimension according to ILSS sample

Specimen	Dimensions (W x T x L) in mm
Glass Fibre symmetric composite	30 X 8 X 3
Glass Fibre asymmetric composite	30 X 8 X 3

Table 3: Specimen dimension according to three point bend test sample

Specimen	Dimensions (W x T x L) in mm
Glass Fibre symmetric composite	46 X 20 X 3
Glass Fibre asymmetric composite	46 X 20 X 3

2.4. Testing configuration

The short beam shear test subjects a beam to bending, the beam is very short relative to its thickness. For example, ASTM D 2344 specifies a support-span-length-to-specimen-thickness ratio (s/t) of only 10:1. The objective is to minimize the flexural (tensile and compressive) stresses and to maximize the induced shear stress. The specimen testing configuration is shown in the Fig.3 respectively.

Fig. 3: ASTM D 2344 Short Beam Specimen Configuration.

3. RESULTS AND DISCUSSION

The ILSS values were evaluated from the short beam shear test according to the following relation:

$$ILSS = \frac{0.75\,P}{bd}$$

Where, P_b = breaking load,

b = width and

d = thickness of the specimen.

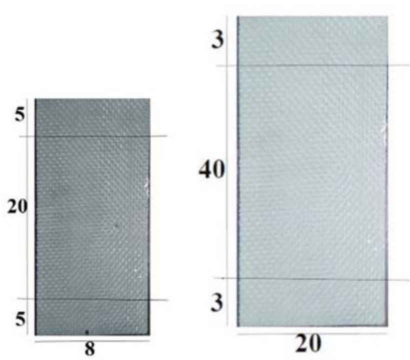

Fig. 4: ILSS sample and three point bend test samples

The average ILSS value of symmetric and asymmetric composite are obtained as 15.03 ± 0.58 MPa and 10.13 ± 0.71 MPa. All the tested ILSS values of different specimens are shown in table 4 and table 5.

Table 4: ILSS values of various glass fibre symmetric reinforced composite specimens

Specimen #	Maximum Load (N)	ILSS (MPa)
1	455	14.21
2	471	14.71
3	485	15.16
4	503	15.71
5	491	15.34
Average	481	15.03
Standard Deviation	18.54	0.58

Fig. 5: ILSS test graph for symmetrical composite laminate.

Table 5: ILSS values of various glass fiber asymmetric reinforced composite specimens

Specimen #	Maximum Load (N)	ILSS (MPa)
1	303	9.46
2	330	10.31
3	298	9.31
4	341	10.66
5	349	10.90
Average	324.2	10.13
Standard Deviation	22.73	0.71

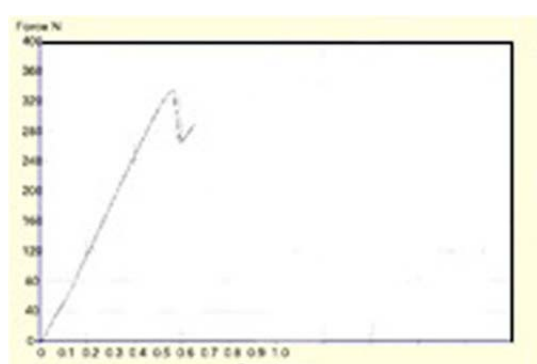

Fig. 6: ILSS test graph for asymmetrical composite laminate.

The average Bending strength value of symmetric and asymmetric composite are obtained as 730N and 606N. All the tested Bending strength values of different specimens are shown in table 6 and table 7.

Table 6: Bending strength values of various glass fibre symmetric reinforced composite specimens.

Specimen #	Maximum Load (N)
1	698
2	717
3	734
4	749
5	752
Average	730

Table 7: Bending strength values of various glass fiberasymmetric reinforced composite specimens.

Specimen #	Maximum Load (N)
1	573
2	592
3	611
4	625
5	629
Average	606

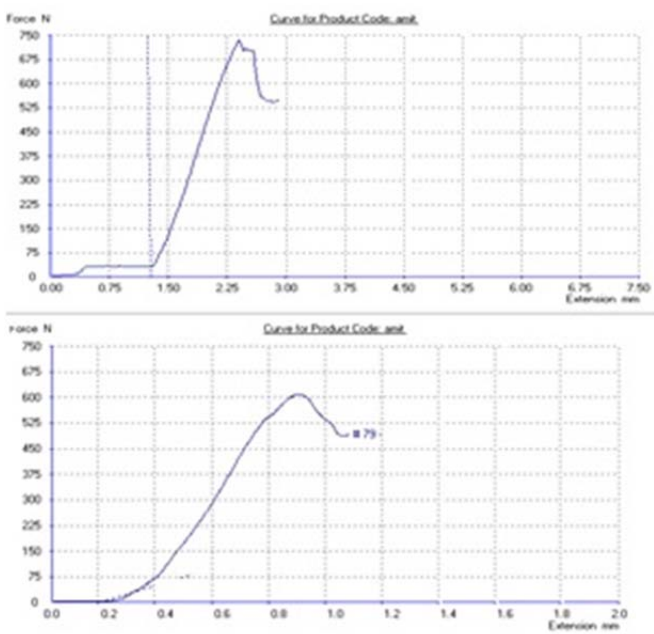

Fig. 7: Three-point bend test graph for symmetrical and asymmetric composite laminates

The ILSS value of glass fiber reinforced symmetric and asymmetric epoxy matrix were also evaluated to know the influence of individual Fibers. This result indicates that the ILSS value predominantly depends on the matrix material and minimal contribution of fibers in the two phase composite materials. For the symmetric material the ILSS value is significantly improved by 48.37%, this is due to the contribution of symmetric glass fibers along with matrix material. Minimum five specimens were tested in each material as per the ASTM D2344.

Fig. 8: Samples after test (a) ILSS, (b) Three point bend test

4. CONCLUSIONS

Interlaminar shear strength of two different materials namely glass-carbon fibers symmetric and asymmetric reinforced epoxy matrix composite was evaluated and the value of symmetric composite is significantly 48.37% higher than asymmetric composite laminate.

S. No.	Samples	Width, mm	Thickness, mm	Inter-laminar shear strength, (MPa)
1	Symmetric	8	3	15.03 ± 0.58
2	Asymmetric	8	3	10.13 ± 0.71

The bending strength of two different materials using 3-point bend test namely glass-carbon fibers symmetric and asymmetric reinforced epoxy matrix composite was evaluated and the value of symmetric composite is significantly 20.46% higher than asymmetric composite laminate.

S. No.	Samples	Width, mm	Thickness, mm	Bending strength, (N)
1	Symmetric	18	3	730
2	Asymmetric	18	3	606

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