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Interlaminar Shear Strength of Carbon Fiber and Glass Fiber Reinforced Epoxy Matrix Hybrid Composite

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Abstract

Hybrid composite Materials have extensive engineering application where strength to weight ratio, low cost and ease of fabrication are required. Hybrid composites provide combination of properties such as tensile modulus, compressive strength and impact strength that cannot be realized in monolithic materials. In recent times hybrid composites have been established as highly efficient, high performance structural materials and their use is increasing rapidly. Hybrid composites are usually used when combinations of properties of different types of fibers have to be achieved, or when longitudinal as well as lateral mechanical performances are required.

In this study, the interlaminar shear strength (ILSS) of glass and carbon fiber reinforced epoxy matrix hybrid composite was studied and to know the influence of glass and carbon fibers individually on ILSS carbon fiber epoxy composite and glass fiber epoxy composite were also prepared and studied extensively. The results show that the ILSS of hybrid composite is significantly improved as compared to glass fiber reinforced composite / carbon fiber reinforced composite.

Keywords - *Hybrid Composites, Short Beam, ILSS, Filament Winding.*

1. Introduction

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 fibers, particles or flake. The matrix phase materials are generally continuous [1, 2].

In recent years, the fiber reinforced polymer 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 lightweight structural materials supporting latest technologies and design concepts for the complex shaped structures like aircraft, automotive structures, and large wind turbine blade structures [4].

Hybrid materials are composites consisting of two constituents at the nanometer or molecular level. Commonly one of these compounds is inorganic and the other one organic in nature. Thus, they differ from traditional composites where the constituents are at the macroscopic (micrometer to millimeter level). Mixing at the microscopic scale leads to a more homogeneous material that either shows characteristics in between the two original phases or even new properties.

The inter-laminar shear strength (ILSS) is one of the most important parameters in determining the ability of a composite to resist delamination damage. An accurate prediction of its value, therefore, is important and a number of tests have been developed for evaluation. Standardized test methods are the three-point-bending tests according to ASTM D2344 for Apparent Inter-laminar Shear Strength of Parallel Fiber 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 interlaminar shear failure takes place [6-8]. In this study glass fiber reinforced composite, carbon fiber reinforced composite and glass-carbon epoxy hybrid composite were manufactured by filament winding process with a curing in a hydraulic press. This paper aimed to study the ILSS of carbon fiber epoxy composite, glass fiber epoxy composite and glass-carbon epoxy hybrid composite.

2. Experimental

2.1. Materials

In this present study, glass-carbon fibers reinforced epoxy matrix hybrid composite, glass fiber reinforced epoxy matrix composite and carbon fiber reinforced epoxy matrix composite were fabricated and tested according to ASTM D2344.

This hybrid composite has alternate layers of glass and carbon fiber laminas. The laminas in a composite laminate can be laid up in different orientations based on the properties required. In this, the properties of a laminate with laminas in different orientations are studied to obtain a laminate with optimum properties in all directions. The properties for various combinations of lamina orientations for the hybrid composite laminate are obtained by AUTODESK software.

The optimum ply orientation for the hybrid composite is decided as $(0^0{}_C/45^0{}_G/45^0{}_C/-45^0{}_G/-45^0{}_C/90^0{}_G/90^0{}_C/)_S$.

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

Table 1: Materials Used

Constituent	Specification
Carbon Fiber	Formasa T6 6K
Glass Fiber	E-Glass 12000Tex
Epoxy	LY 556
Hardener	5200

2.2. Specimen Preparation

Carbon fibers along with E-glass Fiber woven roving were 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 filament winding method. The lamina was initially subjected to an environment drying for tackiness at room temperature for a period of 24 hours.

Thickness of glass fiber reinforced lamina was 0.36 mm and carbon Fiber reinforced lamina was 0.25 mm, these lamina are cut in to pieces of 380 X 340 mm which is the tool size, to prepare a laminate of thickness 3.5 mm, depending on laminate number of plies are stacked to attain required thickness. The tool is then placed in a hydraulic press under a pressure of 15 bar for the extraction of undesirable resin along with exposure to a second environment with a two-step increase in temperature with 80ºC for one hour and 120ºC for next six hours. The time of polymerization for all the samples was 360 min, at 120ºC. Similar procedure and curing cycle was followed to prepare other two materials. Same ply-sequence was followed for all three materials. After samples were formed, test specimens were cutout, which were tested. ILSS specimen dimensions are shown in the Table 2 and the length of specimen includes a span of six times the thickness.

Table 2: Specimen dimension according to ASTM D2344

Specimen	Dimensions (W x T x L) in mm
Glass Fiber composite	8 x 4.06 x 50
Carbon Fiber composite	8 x 3.80 x 50
Hybrid Composite	8 x 3.57 x 50

2.3. 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 6:1. The objective is to minimize the flexural (tensile and compressive) stresses and to maximize the induced shear stress. The specimen and specimen testing configuration are shown in the Fig. 1 and Fig 2. respectively.

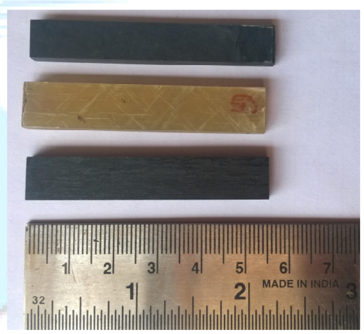

Fig. 1: Specimens used in SBS testing

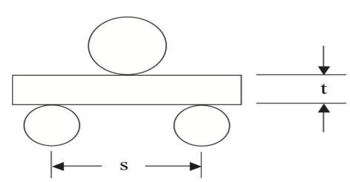

Fig. 2: ASTM D 2344 Short Beam Specimen Configuration.

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3. Results and Discussion

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

$$ILSS = \frac{0.75P_b}{bd}$$

Where P_b = breaking load,
b = width and
d = thickness of the specimen.

The average ILSS value of hybrid composite is obtained as 40.00 ± 1.08 MPa. This is due to the combination of dual reinforcement i.e. carbon and glass Fiber and all the tested ILSS values of different specimens are shown in Table 3.

Table 3: ILSS values of various glass/carbon fiber reinforced hybrid composite specimens

Specimen #	Maximum Load (N)	ILSS (MPa)
1	1470	38.60
2	1530	40.18
3	1567	41.15
4	1493	39.21
5	1556	40.86
Average	1523.2	40.00
Standard Deviation	41.18	1.08

Table 4: ILSS values of various glass fiber reinforced composite specimens

Specimen #	Maximum Load (N)	ILSS (MPa)
1	1192	27.52
2	1220	28.17
3	1227	28.33
4	1176	27.16
5	1288	29.74
Average	1220.6	28.19
Standard Deviation	42.99	0.99

The ILSS value of glass fiber reinforced epoxy matrix composite and carbon fiber reinforced epoxy matrix composite were also evaluated to know the influence of individual Fibers. The ILSS value in glass fiber composite was obtained as 28.19 ± 0.99 MPa (Table 4) and the almost same value is obtained in the case of carbon fiber reinforced epoxy matrix composite 30.11 ± 0.93 MPa (Table 5). 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 Hybrid material (three phase) the ILSS value is significantly improved by 35%, this is due to the contribution of carbon and glass fibers along with matrix material. Minimum five specimens were tested in each material as per the ASTM D2344.

Table 5: ILSS values of various carbon fiber reinforced composite specimens

Specimen #	Maximum Load (N)	ILSS (MPa)
1	1237	30.52
2	1185	29.24
3	1198	29.56
4	1279	31.55
5	1204	29.70
Average	1220.6	30.11
Standard Deviation	37.85	0.93

The comparison of the ILSS of the three materials is shown in the Fig 3.

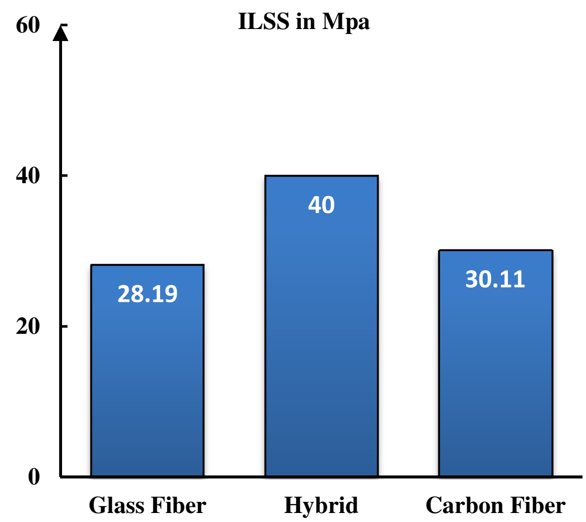

Fig 3: ILSS values of Glass fiber composite, hybrid composite and carbon fiber composite

4. Conclusions

The interlaminar shear strength of three different materials namely glass-carbon fibers reinforced epoxy matrix hybrid composite (three-phase composite), glass fiber reinforced epoxy matrix composite and carbon fiber reinforced epoxy matrix composite (two-phase composites) was evaluated and the value of three-phase composite is significantly higher due to hybrid compositing. In the two-phase composite materials the ILSS value majorly depends on matrix material.

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