Paper published in Journal of aircraft and aerospace engineering, 2007, Volume 79 (1),45-62, Archived in Dspace@nitr http://dspace.nitrkl.ac.in/dspace

Effects of Loading Speed on the Failure Behaviour of FRP Composites

B. Das, S. K. Sahu and B. C. Ray

National Institute of Technology, Rourkela-769008, India

Key Words: Composites, characterization, loading speed, shear strength

Abstract

The objective of the present work is to ascertain the failure modes under different loading speeds along with change in percentage of constituents of FRP composites. This involves experimental investigation of FRP composites with woven roving fibers and matrix. Different types of composites i.e. Glass : Epoxy, Glass : Polyester and (Carbon + Glass) : Epoxy are used in the investigation with change in percentage of constituents. The variability of fiber content of the composite is in the range of 0.55 to 0.65 weight fractions. The matrix dominated property, like inter laminar shear strength has been studied by three point bend test using INSTRON 1195 material testing machine with increasing five cross head velocities. The variation of inter laminar shear strength of laminates of FRP composites is significant for low loading speed and is not so prominent for high speed. The variation of inter laminar shear strengths are observed to be dependent on the type and amount of constituents present in the composites. The laminates with carbon fiber shows higher inter laminar shear strength than that of glass fiber composites. The laminates with epoxy matrix shows higher inter laminar shear strength than polyester matrix composites for the same fiber. There is no significant variation of inter laminar shear strength beyond loading speed 200 mm/min and this can be used for specifications of testing. Matrix resins such as polyester and epoxy are known to be highly rate sensitive. Carbon fiber are relatively rate independent and E – Glass fibers are rate sensitive. Woven roving Carbon Glass Fiber Reinforced Polymer (CGFRP) shows small rate dependence and woven roving Glass Fiber Reinforced Polymer (GFRP) shows significant rate sensitivity.

Introduction

There has been a tremendous advancement in the science and technology of fiber reinforced composites in recent times. The low density, high strength, high stiffness to weight ratio, excellent durability, and design flexibility of fiber reinforced polymers are the primary reasons for their use in many structural components in the aircrafts, automotive, marine and other industries. Fiber-reinforced polymers are now used in application ranging from space craft frames to ladder rails, from aircraft wings to automobile doors, from rocket motor cases to oxygen tanks and from printed circuit boards to tennis rackets. The increasing utilization of polymer composite materials in critical structures necessitates their full characterisation. This will bring about the much needed boost in confidence for their application to industrial situations including building industries where high speed load is a concern. Load speed performance can in some way be measured by the energy absorbed or expended to failure of a material. Hence establishing the effects of failure behavior of materials of different fibers is of paramount importance when designing for load speed. The strength properties of FRP composite materials are based on the content of fiber and matrix material. Glass fiber and carbon fiber based polymeric composites are finding wider and newer applications in different fields. Recently Beamount (1989) presented an overview of the investigations on failure behaviour of composite materials. Daniel and Ishai (1994) presented an excellent review of the previous studies on experimental methods for characterization and testing of composite materials through 1994. Mannini [1997] investigated the thermal buckling of symmetric and anti symmetric cross ply composites laminates. A parametric study for several types of laminates was given for different boundary conditions and changing the values of various parameters such as lay up sequences slenderness ratio and transverse shear moduli. The buckling parameter reduced when the slenderness ratio decreased and increasing the transverse shear modulus would provide a higher thermal buckling. Keusch, Queck and Gliesche [1998] investigated the influence of the interface of differently sized glass fibers on the mechanical properties of glass fiber epoxy resin composites. The results of micromechanical and macro mechanical tests of unidirectional laminates characterize the fiber/matrix adhesion. Deng *et al*. [1999] conducted a comprehensive experimental study to identify the effects of fiber cross sectional aspect ratio on tensile and flexural properties and the failure modes of glass fiber/epoxy composites by using fibers of three different cross sectional shapes (round, peanut shaped and oval). It was found that, the fibers of peanut and oval cross sectional shapes tend to align with the long axis of the cross section perpendicular to the direction of the applied pressure or in the plane of a composite laminate. As a result, many fibers overlapped each other, having large contact areas which act as a path for longitudinal crack propagation. The longitudinal tensile modulus and strength were nearly the same for the three composite systems. The transverse tensile strength and strain to failure results were similar to those for longitudinal tension but the transverse tensile modulus was reduced for composites with fibers of large aspect ratios. Okoli and Smith [2000] performed tensile tests on a glass epoxy laminate at different rates of strain to determine the effects of strain rate in the Poisson's ratio of the material. The findings from the experimental results suggested that poisson's ratio is not sensitive to strain rate. However the extent to which fiber content affects the rate sensitivity of

Poisson's ratio is yet to be established. Okoli [2001] conducted tensile, shear and 3 point bend tests on woven glass epoxy laminate at increasing rates of strain to ascertain the relationship between energy to failure and strain rate. The result suggested a linear relationship between expended energy and the log of strain rate in the laminate tested. Silva *et al*.[2001] investigated the effect of the addition of Methyl ethyl keytone peroxide (MEKP) and Cobalt naphthenate (CoNaph) on the mechanical behavior of epoxy vinyl ester resin (EVER) laminates by using a factorial experimental design in which the MEKP and Naph Co contents were vary. The result showed that there is an interaction between the process variables analysed, MEKP and CoNaph contents on the mechanical properties. Okutan (2001) studied the effects of geometric parameters on the failure strength for pin loaded fiberglass reinforced epoxy laminate.

The objective of the present study is to investigate the effect of loading speed on the failure behaviour of different types of fiber reinforced composites. The macroscopic property changes of FRP composites can be ascertained by mechanical tests such as three point bend test, which gives an idea about the inter laminar shear strength. Three types of composite laminates with woven fiber reinforcement i.e. (i) Glass : Epoxy (ii) Glass : Polyester and (iii) (Carbon + Glass): Epoxy with different weight fractions are fabricated and specimens are tested to failure by three point bend test in five different increasing load speeds on an INSTRON 1195 material testing machine. The test results are analysed to characterize the effects of fiber types and loading speed on failure behavior of FRP composites.

Experimental Work

In the present investigation, three different types of fiber : matrix composites specimens were fabricated. These were (i) (Carbon + Glass) : Epoxy (ii) Glass : Epoxy (iii) Glass : Polyester. Each type of preparation of laminates were manufactured of three different type of weight fractions of fiber : matrix i.e. 55 : 45, 60:40 and 65:35. Woven roving E-Glass and Woven roving carbon fibers were cut in to required shape and size according to no. of specimens required for testing. Each composite laminate consists of 16 plies of fiber as per ASTM specification (1990). For glass epoxy specimens, three varieties of laminates were prepared i.e. (i) Glass : Epoxy = 55 : 45 (ii) Glass : Epoxy = 60:40 (iii) Glass : Epoxy = 65 : 35. The epoxy resins are (i) Araldite LY 556 (ii) Hardener HY951. For preparation of epoxy resin matrix 3% Hardeners were used. Similarly three glass – polyester laminates were fabricated i.e. (i) Glass : Polyester = 55 : 45, (ii) Glass : Polyester = 60 :40 and (iii) Glass : Polyester = 65 :35. For preparation of polyester matrix 1% accelerator was added first to the polyester resin. Then 1.5% catalyst added to mixture and stirred thoroughly to get polyester matrix. The accelerator and catalyst were used Cobalt Octate 2 % and MEKP (Methyl Ethyl Ketone Peroxide) respectively. Then three types of (Carbon+Glass) : Epoxy hybrid laminates were fabricated i.e. (Carbon + Glass) : Epoxy = 55 :45 (ii) (Carbon + Glass) : Epoxy = 60:40 and (iii) (Carbon + Glass): Epoxy = 65 : 35. Subsequent plies were placed one upon another with matrix in each layer to obtain sixteen stacking plies. A hand roller was used to distribute resin uniformly, compact plies, and to remove entrapped air. The mold and lay up were covered with a release film to prevent the lay up from bonding to the mold surface. Then the resin impregnated fibers were placed in the mold for curing. The laminates were cured at normal temperature (25^0C and 55 % Relative Humidity) under a pressure of 0.2 MPa for 3 days. The objective was to ensure good bonding of the resin and reinforcement. After proper curing of the laminates the release films were detached. In (Carbon + Glass) : Epoxy hybrid laminate, there are eight carbon fiber plies and eight glass fiber plies. They were placed alternatively one upon another with matrix in each layer. From the laminates of each is weight fraction of fiber matrix, specimens were cut for three point bend test by brick cutting machine into 45 mm X 6mm size as per specification. Inter laminar shear strength is a measure of the in-situ shear strength of the matrix layer between plies. The most commonly used test for inter laminar shear strength (ILSS) is the short beam under three point bending. The specimens were tested for 3 point bend test on the INSTRON 1195 material testing machine with different cross head velocities to obtain inter laminar shear strength and to study the effects of loading speed for different types of laminates. The tests were conducted with cross head velocities 2 mm / min, 20mm / min, 100mm / min, 200 mm / min, 500 mm / min with constant span of 34 mm. Then load at yield (max. load) were obtained for each specimens as shown in Table 1 to 9. For each type of laminate minimum ten specimens were tested with different cross head velocities. The important procedures were followed during 3 point bend test as follows. Before testing the thickness and width of the specimens were measured accurately at the midpoint. The test specimen was placed in the test fixture and aligned so that its midpoint was centered and it's long axis was perpendicular to the loading nose. The load was applied to the specimen at a specified cross head speed. Breaking load of the sample was recorded. The same procedure was repeated for all the specimens. The inter laminar shear strength was calculated using the formula, $S = (0.75P_b)/(bd)$ [as per ASTM D 2344 – 84]

Where, P_b = Breaking load, kg.

b = Width, mm., d = Thickness, mm.

Results and discussion

The details of dimensions of the Glass fiber and epoxy matrix test specimens and the yield load under three point bend tests are shown in Table 3.1 to 3.3 and the variation of inter laminar shear strength Vs. loading speed are shown in Fig. 3.1.

Table – 3.1 : Test Results of Glass Fiber : Epoxy = 55:45 Specimens

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength ($0.75\ P_b/bd$) (Mpa)	Average Inter laminar shear strength (Mpa)	Loading speed (mm/min)
2	5.64	4.41	1063	32.1	30.9	2
3	6.14	4.49	1089	29.6		2
4	6.97	4.35	1041	25.8	27.1	20
5	6.18	4.68	1092	28.3		20
7	6.48	4.75	734.8	17.9	17.9	100
8	6.73	4.71	954.9	22.6	23.4	200
9	6.11	4.47	878.3	24.1		200
12	6.16	4.65	1088	28.5	23.3	500
13	5.99	4.78	689.3	18.1		500

Table – 3.2 : Test Results of Glass Fiber : Epoxy = 60:40 Specimens

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength ($0.75\ P_b/bd$) (Mpa)	Average Inter laminar shear strength (Mpa)	Loading speed (mm/min)
166	5.75	4.55	1206	34.6	32.9	2
165	6.15	5.25	1339	31.1		2
179	5.84	5.18	1260	31.2	32.5	20
178	5.84	5.14	1347	33.7		20
209	6.15	5.07	791	19	20	100
163	7.11	5.05	1005	21		100
226	6.44	5.14	1093	24.8	23.4	200
175	6.24	5.20	949.8	22		200
159	5.27	4.97	899.7	25.7	24.7	500
161	6.21	5.32	1042	23.7		500

Table – 3.3 :Test Results of Glass Fiber : Epoxy = 65:35 Specimens

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength ($0.75\ P_b/bd$) (Mpa)	Average Inter laminar shear strength (Mpa)	Loading speed (mm/ min)
287	6.50	5.17	1369	30.6	31.5	2
288	6.14	4.52	1196	32.3		2
289	6.69	4.73	1449	34.3	33.9	20
290	5.79	5.17	1337	33.5		20
291	6.82	5.10	985	21.2	24.8	100
292	6.50	4.55	1118	28.4		100
293	6.39	4.83	837.4	20.3	23.5	200
294	6.86	4.71	1144	26.6		200
297	6.18	4.88	1031	25.6	27	500
298	6.2	4.57	1072	28.4		500

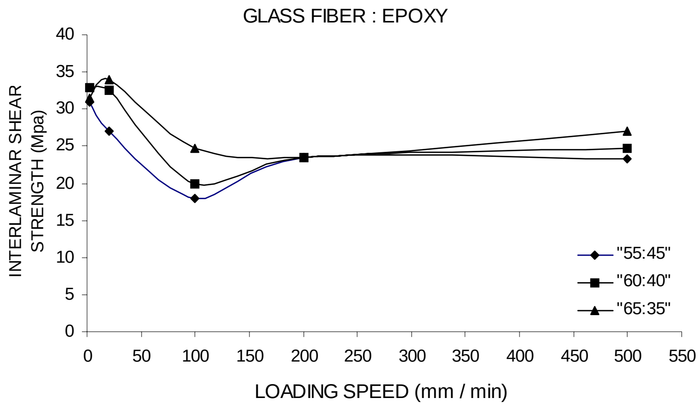

Figure 3.1 : Inter laminar shear strength vs. loading speed diagram of glass : epoxy at different weight fractions of fiber matrix composites

Table – 3.4 : Test Results of Glass Fiber : Polyester = 55:45 Specimens

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength (0.75 P_b/bd) (Mpa)	Average Inter laminar shear strength (Mpa)	Loading speed (mm/ min)
1	6.64	5.54	970.3	19.8	19.5	2
2	6.73	5.51	949.9	19.2		2
3	6.56	5.59	1391	28.4	28.4	20
4	6.28	5.47	1299	28.4		20
5	6.45	5.18	5878	131.9	91.1	100
6	6.69	5.54	2486	50.3		100
7	6.4	5.1	936.2	21.5	19.8	200
8	6.48	5.51	956.6	20.1		200
12	6.46	5.33	817.1	17.8		200
9	6.58	5.52	967.8	20	20.2	500
10	6.17	5.49	881.2	19.5		500
11	6.76	5.42	1028	21		500

Table – 3.5 : Test Results of Glass Fiber : Polyester = 60:40 Specimens.

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength (0.75 P_b/bd) (Mpa)	Average Inter laminar shear strength (Mpa)	Loading speed (mm/ min)
1	6.72	4.82	998.3	23.1	24.8	2
2	6.46	5.16	1172	26.4		2
3	6.51	5.26	1385	30.3	29.7	20
4	6.56	5.23	1329	29.1		20
5	6.65	4.82	1019	23.8	21.8	100
6	6.58	4.92	856.2	19.8		100
7	6.68	5.12	992.2	21.8	22.6	200
8	6.64	5.04	1007	22.6		200
14	6.28	5.10	999.7	23.4		200
10	6.44	5.30	906.6	19.9	21.5	500
11	6.52	5.20	1034	22.9		500
12	6.48	4.92	926.7	21.8		500

The details of dimensions of the Glass fiber and polyster matrix test specimens and the yield load under three point bend tests are shown in Table 3.4 to 3.6 and the variation of inter laminar shear strength Vs. loading speed are shown in Fig. 3.2.

Table – 3.6:Test Results of Glass Fiber : Polyester = 65:35 Specimens**.**

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength (0.75 P_b/bd) (Mpa)	Average Inter laminar shear strength (Mpa)	Loading speed (mm/ min)
1	6.48	5.04	1080	24.8	21.4	2
2	6.50	5.10	797.1	18		2
3	6.22	5.10	1105	26.1	28.1	20
4	6.40	5.14	1319	30		20
5	6.52	5.22	912.2	20.1	21.3	100
6	6.54	5.02	978.5	22.4		100
7	6.56	5.10	880.2	19.7	20.7	200
8	6.50	5.11	966.7	21.8		200
14	6.26	5.00	865.2	20.7		200
9	6.58	5.12	789.5	17.6	18.3	500
10	6.43	4.92	825.1	19.6		500
13	6.43	4.99	758.5	17.7		500

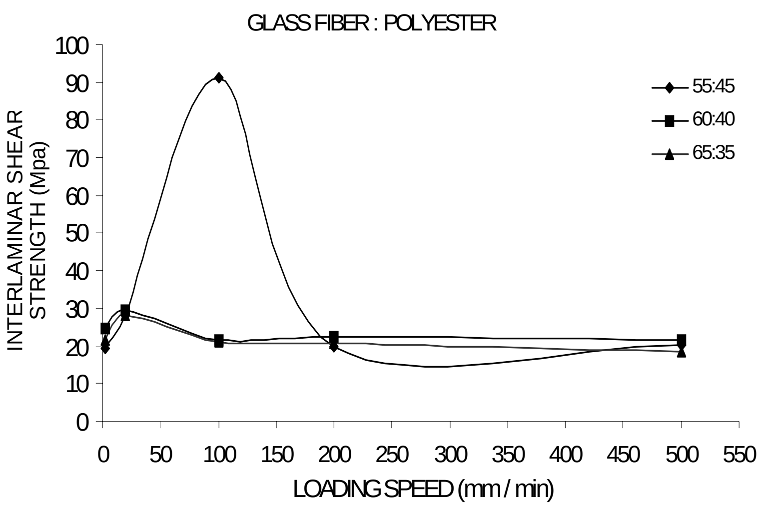

Figure 3.2 : Inter laminar shear strength vs. loading speed diagram of glass : polyester at different weight fractions of fiber matrix composites

The details of dimensions of the (carbon+glass) fiber and epoxy matrix test specimens and the yield load under three point bend tests are shown in table 3.7 to 3.9 and the variation of inter laminar shear strength Vs. loading speed are shown in fig. 3.3.

Table – 3.7 : Test Results of (Carbon + Glass) : Epoxy = 55:45 Specimens.

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength (0.75 P_b/bd) (Mpa))	Average Inter laminar shear strength (Mpa)	Loading speed (mm/ min)
1	6.19	6.64	2211	40.35	37.7	2
2	6.58	6.83	2105	35.13		2
3	6.29	5.66	1774	37.37	39.7	20
4	6.26	6.22	2178	41.95		20
5	6.51	5.98	1676	32.29	31.4	100
6	5.86	6.37	1519	30.52		100
7	6.00	5.94	1661	34.95	33.4	200
8	6.32	5.64	1509	31.75		200
9	6.28	6.10	1636	32.03	32.8	500
10	6.23	6.79	1898	33.65		500

Table – 3.8 : Test Results of (Carbon + Glass) : Epoxy = 60:40 Specimens.

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength (0.75 P_b/bd) (Mpa)	Average Inter laminar shear strength (Mpa)	Loading speed (mm/ min)
1	6.19	5.98	2130	43.16	40.7	2
2	6.34	6.50	2100	38.22		2
3	5.85	6.25	1935	39.69	40.6	20
4	6.00	6.85	2279	41.59		20
5	6.36	6.50	1585	28.76	29.8	100
6	6.15	6.87	1737	30.83		100
7	6.21	6.97	1701	29.47	30.4	200
8	6.61	6.41	1767	31.28		200
9	6.31	6.39	1666	30.99	31.2	500
10	5.91	6.87	1696	31.33		500

Table – 3.9 : Test Results of (Carbon + Glass) : Epoxy = 65 : 35 Specimens.

Sample No.	Width (mm) (b)	Thickness (mm) (d)	Load at yield (max load) (N) (P_b)	Inter laminar Shear strength (0.75 P_b/bd) (Mpa)	Average Inter laminar shear strength (Mpa)	Loading speed (mm/ min)
1	6.24	5.75	1484	31.02	34.5	2
2	6.06	6.34	1949	38.04		2
3	6.14	6.15	2057	40.85	39.7	20
4	6.18	6.07	1925	38.48		20
6	5.95	6.30	1540	30.81	27.6	100
13	5.55	6.32	1141	24.4		100
7	6.04	5.95	1328	27.71	27.3	200
8	6.71	6.27	1509	26.9		200
9	6.11	6.09	1641	33.07	31.4	500
10	6.49	5.69	1459	29.63		500

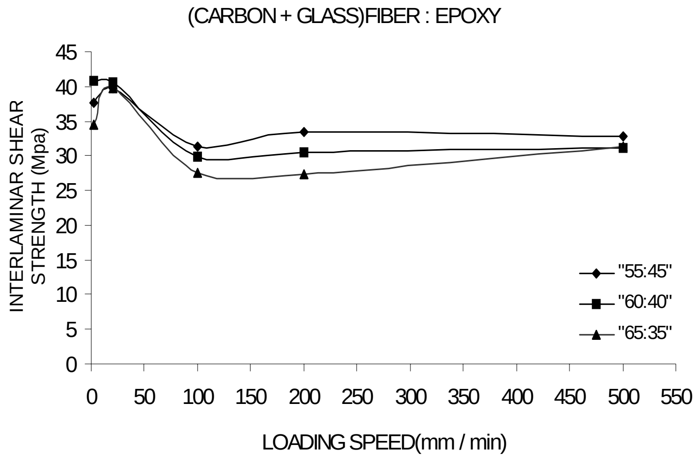

Figure 3.3 : Inter laminar shear strength vs. loading speed diagram of (Carbon + glass) : Epoxy at different weight fractions of fiber matrix composites.

The variations of inter laminar shear strength on the weight fractions, loading speed, fiber and matrix types of the FRP composites are discussed below.

Effects of weight fractions

In the weight fraction of fiber-matrix of glass-epoxy, higher fiber percent content gives higher inter laminar shear strength in low loading speed as well as high loading speed than lower fiber percent content of fiber : matrix while in weight fraction of fiber : matrix of (carbon + Glass) : Epoxy lower fiber percent content gives higher inter laminar shear strength in low loading speed as well as high loading speed than higher fiber percent content of fiber-matrix. In the loading speed of 200 mm/min, the inter laminar shear strength is constant irrespective of weight fraction of fiber matrix of glass : epoxy while in loading speed20 mm/min, the inter laminar shear strengths are constant irrespective of weight fraction of fiber : matrix of glass : polyester and (carbon + Glass) : Epoxy specimens. In high loading speed 500 mm/min the inter laminar shear strength is constant for weight - fraction of fiber-matrix of (carbon + Glass) : Epoxy=60:40 and (carbon + Glass) : Epoxy=65:35 specimens.

Effects of loading rates

The inter laminar shear strength is higher at low loading speed and the inter laminar shear strength is lower at high loading speed for a particular weight – fraction of fiber : matrix of Glass : Epoxy and (carbon + Glass) : Epoxy specimens. In higher loading speed i.e. 200 mm/min to 500 mm/min optimum fiber : matrix of glass : polyester = 60:40 gives the higher inter laminar shear strength while in 100 mm/min loading speed Glass : Polyester = 55 : 45 gives the maximum inter laminar shear strength. Matrix resins such as Polyester and Epoxy are known to be highly rate sensitive. In general, the variation of inter laminar shear strengths are found with increasing loading speed. E-Glass fibers have been found to be rate sensitive but very little information is available on the rate dependence of the carbon fibers. One should in general anticipate some rate dependency of composites, although a direct correlation between the rate dependency of the composite and those of the constituent phases, can be difficult or rather complicated. Woven roving Glass Fiber Reinforced Polymer (GFRP) show a significant rate sensitivity. The variation of inter laminar shear strengths are found with increasing loading speed. The lack of a significant rate dependency of Carbon Glass Fiber Reinforced Polymer (CGFRP) likely reflects the lack of rate dependence of the carbon fiber. It is important to note that a change in loading speed can result in a variation of failure modes. A small rate dependence of the strength has been observed with woven reinforcement Carbon Glass Fiber Reinforced Polymer (CGFRP).When subjected to an increasingly higher impact velocity, a laminate behaves like a more rigid beam or plate, less susceptible to bending. This shifts its behavior from that of a flexible beam (very low impact velocity), with failure preferentially initiated from the rear surface, to that of a rigid beam, with damage initiation occurring near the point of contact in the case of much higher impact velocity. At intermediate velocities, one should expect to see complex behavior of mixed fracture modes. This has yet to be verified by a systematic study.

Effects of different fiber types

The variation of inter laminar shear strengths for Epoxy laminates with (Carbon + Glass) and Glass fibers of weight fraction 55:45 are shown in Table 3.7 and Table 3.1 respectively. As seen from Table 3.7 and Table 3.1, for all loading speed, the Inter Laminar Shear Strength (ILSS) for laminates with (Carbon + Glass) fiber is higher than Glass fiber laminates for same matrix. The variation of Inter laminar shear strength for epoxy laminates with (Carbon + Glass) and Glass fibers of weight fraction 60 :40 are shown in Table 3.8 and 3.2 respectively. As seen from Table 3.8 and Table 3.2, for all loading speed the Inter Laminar Shear Strength (ILSS) for laminates with (Carbon + Glass) fiber is higher than Glass fiber laminates for same matrix. The variation of inter laminar shear strength for epoxy laminates with (Carbon + Glass) and Glass fibers of weight fraction 65:35 are shown in Table 3.9 and Table 3.3 respectively. As seen from Table 3.9 and Table 3.3, for all loading speed, the Inter Laminar Shear Strength (ILSS) for laminates with (Carbon + Glass) fiber is higher than Glass fiber laminates for same matrix. So it is concluded that, the laminates with carbon fiber shows higher inter laminar shear strength than that of Glass fiber for same matrix.

Effects of different matrix types

The variation of Inter Laminar shear strengths for Glass fiber laminates with Epoxy and Polyester matrix of weight fraction 55:45 are shown in Table 3.1 and Table 3.4 respectively. As seen from the Table 3.1 and Table 3.4, for all loading speed the Inter Laminar Shear Strength (ILSS) for laminates with epoxy matrix is higher than polyester matrix laminates except for loading speed 20 mm / min and 100 mm / min. There is a general trend of increase of ILSS with epoxy matrix than polyester matrix for same fiber. The variation of Inter Laminar shear strengths for Glass fiber laminates with Epoxy and Polyester matrix of weight fraction 60:40 are shown in Table 3.2 and Table 3.5 respectively. As seen from the Table 3.2 and Table 3.5, for all loading speed the Inter Laminar Shear Strength (ILSS) for laminates with epoxy matrix is higher than polyester matrix laminates for same fiber. The variation of Inter Laminar shear strengths for Glass fiber laminates with Epoxy and Polyester matrix of weight fraction 65:35 are shown in Table 3.3 and Table 3.6 respectively. As seen from the Table 3.3 and Table 3.6, for all loading speed the Inter Laminar Shear Strength (ILSS) for laminates with epoxy matrix is higher than polyester matrix laminates for same fiber. So it is concluded that the laminates with epoxy matrix shows higher inter laminar shear strengths than polyester matrix for the same fiber.

Conclusion

The fabrication of samples and subsequent three point bend test is revealed to ascertain the effects of fiber types and loading speed on the failure behavior of FRP composites. The following conclusions were arrived during the present study had its own limitations with regard to limited laboratory facilities available. It may be noted that validity of these can only be assessed to the range of variables covered and the materials used during the investigation.

- In the weight fraction of fiber matrix of glass : epoxy composites, higher fiber content gives higher inter laminar shear strength, in all loading speeds.
- For (carbon + glass) : epoxy composites, lower fiber content gives higher inter laminar shear strength in all loading speeds.
- The variation of Inter laminar shear strengths of laminates of FRP composites significant for low loading speed and is not so prominent for high speed.
- The variation of Inter laminar shear strengths are observe to be dependent on the type and amount of constituents present in the composites.
- The composite laminates with carbon fiber shows higher inter laminar shear strength than that of glass fiber.
- The composite laminates with epoxy matrix shows higher inter laminar shear strength than polyester matrix for the same fiber.
- There is no significant variations of inter laminar shear strength beyond loading speed 200 mm/min and this can be used for specifications of testing.
- Matrix resins such as polyester and epoxy are known to be highly rate sensitive.

- E-Glass fibers are found to be rate sensitive.
- Carbon fibers are relatively rate independent.
- Woven roving Glass Fiber Reinforced Polymer (GFRP) shows significant rate sensitivity.
- Woven roving Carbon Glass Fiber Reinforced Polymer (CGFRP) shows small rate dependence.

References

ASTM Standards and literature references for composite materials (1990), 2nd edition, American Society for testing and materials, Philadelphia, PA.

Beaumont, P.W.R (1989), "The failure of fiber composites : An over view"; *Journal of Strain Analysis*, Vol. 24, No 4,

Daniel, M. , Ishai, O(1994)., Engineering Mechanics of Composite Materials, Oxford University Press, Oxford.

Deng, Shiqiang., Ye, Lin., & Mai, Yiu-Wing.(1999), "Influence of fiber cross-sectional aspect ratio on mechanical properties of glass fiber/epoxy composites, 1. tensile and flexure behavior",*Composite Science and Technology* volume 59 1331-1339.

Keusch, S., Queck, H., & Gliesche, K.(1998), "Influence of glass fiber/epoxy resin interface on static mechanical properties of unidirectional composites and an fatigue performance of cross ply composites". *Composites* Part A volume 29 A, 701-705

Mannini, A.(1997)., "Shear deformation effects on thermal buckling of cross-ply composite laminates". Composite structures, Vol. 39, NO. 1-2, PP. 1-10.

Okoli, O.I., and Smith G.F.(2000), "The effect of strain rate and fiber content on the Poisson's ratio of glass/epoxy composites". Composite Structures, volume 48, 157-161.

Okutan, Buket.(2002), "The effects of geometric parameters on the failure strength for pin loaded multi directional fiberglass reinforced epoxy laminate". *Composites*: Part B Vol. 33, 567-578.

Okoli, Okenwa, I.(2001), "The effects of strain rate and failure modes on the failure energy of fiber reinforced composites". *Composite Structures,* Volume 54, 299-303.

Silva, A. L. Nazareth d., Teixeira, S.C.S., Widal, A.C.C., & Coutinho, F.M.B.(2001), "Material Properties, mechanical Properties of Polymer composites based on commercial epoxy vinyl ester resin and glass fiber", *Polymer Testing* volume 20, 895-899.