International Journal of Research in Advent Technology, Special Issue, March 2019
E-ISSN: 2321-9637
3rd National Conference on Recent Trends & Innovations In Mechanical Engineering
15th & 16th March 2019
Available online at www.ijrat.org

Linear Elastic Fracture Behaviour Of Glass Fiber Reinforced Polymer Matrix Composite

[1]K. Chandra Shekar*, [2]B. Singaravel, [3]S. Deva Prasad, [4]N. Venkateshwarlu
[1]Professor, Mechanical Engineering, Vignan Institute of Technology and Science, Hyderabad
[2]Associate Professor, Mechanical Engineering, Vignan Institute of Technology and Science, Hyderabad
[3]Professor, Mechanical Engineering, Vignan Institute of Technology and Science, Hyderabad
[4]Associate Professor, Mechanical Engineering, Vignan Institute of Technology and Science, Hyderabad
Corresponding author e-mail: kcschandra2003@gmail.com[1]

Abstract: The present study investigated the effect of glass fiber orientation on the plane strain fracture toughness of glass fiber reinforced polymer matrix composite. The filament winding technique was employed for the synthesis of composite. The fracture toughness in both longitudinal and transverse orientations is carried out by using three point bend test and scanning electron microscopic studies are also carried out to study the fracture mechanism. From the experimental results, it was found that fracture toughness of the glass fiber reinforced composite is significantly higher in longitudinal orientation as compared to transverse orientation of fibers; and more importantly show that such anisotropy is of an order of magnitude and higher.

Keywords-Fracture toughness, Glass fibers, Fractography, Polymer matrix.

1. INTRODUCTION

Polymer matrix composite design methodology consists of many plies, which are dictated by the mechanical property requirements of the product or component. In a composite 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 continuous fiber reinforced polymer matrix 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 sciatic 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]. In this study polymer matrix composite reinforcing with glass fibers was prepared by using filament winding technique. The plane strain fracture toughness was evaluated in two different orientation of fibers i.e., longitudinal (fibers are aligned in the direction of length) and transverse (fibers are aligned in the direction of width). The main purpose of this study is to find out the degree of anisotropy.

2. EXPERIMENTAL

2.1 Materials

In this present study the polymer matrix prepared by using LY 556 epoxy resin and Aradur 5200 hardener. E-glass fibers of 12000 Tex tows were used as reinforcing material. The synthesis was carried out by filament winding technique [5].

2.2 Material Processing

Filament winding technique was used for the preparation of composite lamina. The tension required for the glass fiber is imparted at the creel stand so that the winding process can be carried out without any difficulty of lose fibers while the process of winding [6, 7]. The resin mixture consists with the constituents of thermosetting cross linked epoxy resin and hardener is prepared for the fabrication of composite. The ratio at which the constituents are mixed at 100:27 parts by weight. To prepare the resin mixture all the things required are cleaned thoroughly with acetone to remove the dirt from the instruments. The resin, hardener, diluents are measured separately in a beaker according to the required quantity and mixed thoroughly with a stirrer as shown in Figure 1.

Figure 1: (a) Resin mixing and (b) Creel Stand

The thermos setting epoxy resin is the primary constituent in the laminate, which is the matrix phase of the composite. The hardener acts as initiator or catalyst for the curing to take place for the formation of the laminate. The diluent decreases the viscosity of the resin so that the resin can be impregnated on to the fiber with ease.

The resin mixture is then poured into the resin bath of one-liter capacity in which the glass fiber is impregnated with the resin mixture. The resin bath consists of a comb, a doctor blade, a drum, and scraper blade. The glass fiber roving that is mounted on the creel stand is passed through the provisions provided with a tension applied through the resin bath on to the filament machine shown in Figure 2, where the mandrel/drum used for the winding process. The doctor blade maintains a uniform thickness of resin over the drum and the fiber is passed over the drum that is partially immersed in the resin mixture. The drum rotates as the fiber is passed over the drum that partially takes resin on to its surface and impresses the glass fiber with resin. The scraper blade, which is placed after the drum, removes the extra resin from the fiber so that there is a uniform resin distribution over on to the fiber.

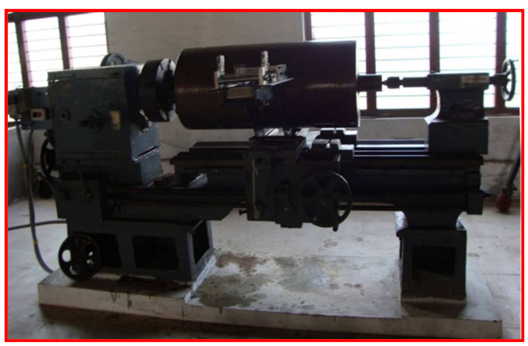

Figure 2: Filament Winding Machine

These fibers are wound on the filament-winding lathe on a cylindrical drum and are cut to form a sheet. This sheet is cut into several pieces depending upon the required orientations and the number of pies. 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 80^{o}C for one hour and 120^{o}C for next six hours. The time of polymerization for all the samples was 360 min, at 120^{o}C. Similar procedure and curing cycle was followed to prepare other two materials. After samples were formed, test specimens were cutout, which were tested. In the present composite the volume fraction of fibers found to be 58.63%.

2.3 Fracture toughness

Fracture toughness is an indication of the amount of stress required to propagate a preexisting flaw. It is a very important material property since the occurrence of flaws is not completely avoidable in the processing, fabrication, or service of a material/component. It is common practice to assume that a flaw of some chosen size will be present in some number of components and use the linear elastic fracture mechanics (LEFM) approach to design critical components. This approach uses the flaw size and features, component geometry, loading conditions and the material property called fracture toughness to evaluate the ability of a component containing a flaw to resist fracture. Mode I fracture is the condition in which the crack plane is normal to the direction of largest tensile loading. All the specimens were prepared as per ASTM standard D5045-99. Pre crack in all the specimens introduced by using razor blade. The ratio of a/w maintains in all the specimens is in between 0.45 to 0.55. The specimen specifications are approximately 40 mm span length, 10 mm width and 3 mm thickness. The specimen dimension satisfies the plane strain conditions as per ASTM standard. Cross head speed maintained 10 mm/min as per ASTM standard.

The plane strain fracture toughness (K_{IC}) calculated by the following equation:

$$K_{IC} = (P/BW^{1/2}) * f(x)$$

Where, P = Maximum load, B = Thickness of the specimen, W = Width of the specimen, x =a/w

$$f(x) = 6x^{1/2} * \frac{[1.99-x(1-x)(2.15-3.93x+2.7x^2)]}{[(1+2x)(1-x)^{3/2}]}$$

3. RESULTS AND DISCUSSION

3.1 Plane strain Fracture toughness

For the sake of clarity five samples are made to cut in such a way that the orientation of fibers is along the length of the specimen. Each of these specimens is designates and notch is prepared according to the varying a/W ratios. The width of the specimen and length of the notch are carefully measured using Vernier calipers. The toughness values for these specimens are expected to be higher. Apart from the above 5 samples, the remaining are oriented in transverse direction. As the fibers are perpendicular to the applied load, therefore the toughness values of these specimens are expected to be much lesser when compared to logitudinal orientation specimens. All the load vs displacement curves of longitudinal specimens has shown a stable crack extension in all the specimens.This is because, these samples the fiber material bears the entire load and there is a minimal contribution of the matrix material. In such specimens, the crack propagation is perpendicular to the direction of fibers and it is hard to break.

Whereas in the transvers specimens, it fails suddenly after reaching the maximum load because in these samples, the matrix material bears the entire load and there is minimal contribution of the fibers and the crack propagation is parallel to the direction of fibers. All the values are given in table 1 and 2 which clearly reveals that, the value of K_{Ic} is significantly greater in laongitudinal direction(10.11 MPa√m) as compared to transverse direction (0.24 MPa√m).

Table 1: Fracture toughness values for various specimens in longitudinal direction

Specimen No	**B (mm)**	**W (mm)**	**a (mm)**	**a/W**	**f(a/W)**	**P_{max} (N)**	**K_{max} (MPa $m^{1/2}$)**	**P_Q (N)**	**K_Q (MPa $m^{1/2}$)**	**P_{max}/P_Q**
FT-L1	3.02	10.35	4.82	0.46	10.65	345.39	12.26	316.87	11.25	1.093
FT-L2	3.05	10.45	4.92	0.47	10.98	282.67	10.03	259.56	09.21	1.089
FT-L3	3.06	9.92	4.73	0.476	10.45	180.66	06.41	168.68	09.98	1.069
FT-L4	3.07	10.44	4.66	0.491	10.32	299.85	09.84	283.14	09.54	1.054
FT-L5	3.05	10.12	4.95	0.489	10.25	320.53	11.25	298.72	10.56	1.073

Table 2: Fracture toughness values for various specimens in transverse direction

Specimen No	**B (mm)**	**W (mm)**	**a (mm)**	**a/W**	**f(a/W)**	**P_{max} (N)**	**K_{max} (MPa $m^{1/2}$)**	**P_Q (N)**	**K_Q (MPa $m^{1/2}$)**	**P_{max}/P_Q**
FT-T1	3.01	10.15	4.82	0.46	10.65	7.5	0.277	7.1	0.25	1.093
FT-T2	3.03	10.23	4.95	0.47	10.98	6.9	0.351	6.33	0.32	1.089
FT-T3	3.05	10.19	4.73	0.476	10.45	8.98	0.331	8.40	0.31	1.069
FT-T4	3.04	10.15	4.66	0.491	10.32	9.10	0.305	8.63	0.29	1.054

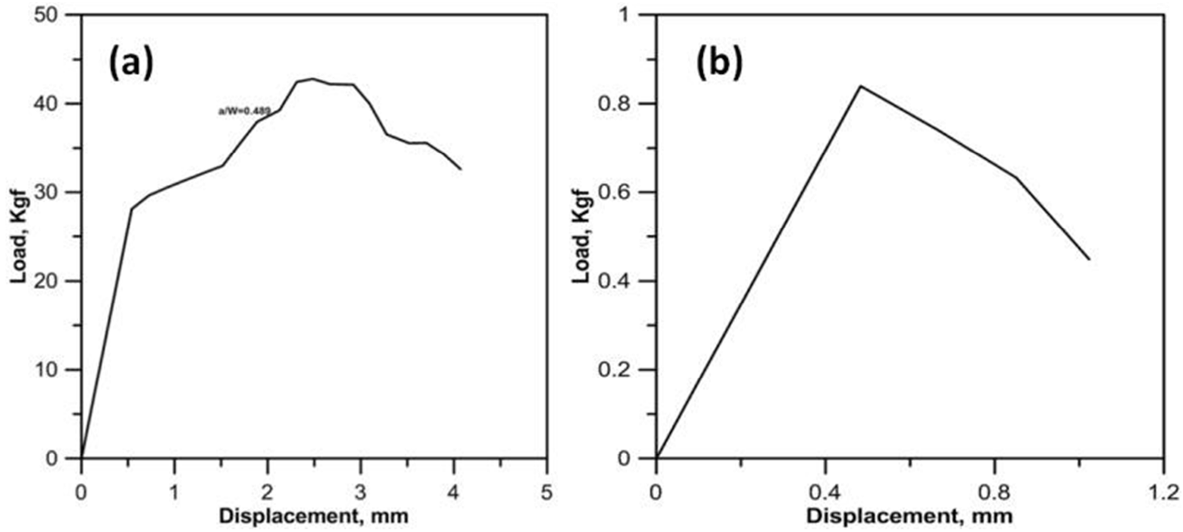

Figure 3: Load Vs Displacement data of (a) Longitudinal (b) Transverse composite specimens

4. FACTOGRAPHY

The fractographs (Figure 4a and 4b) clearly shows fracture of matrix and fiber surface. The fractured morphologies indicate that the Inter laminar failure mainly resulted from the delamination of layers. The fracture of the matrix and debonding of fibre/matrix interface are the main fracture mechanisms in these glass fibre reinforced epoxy matrix composites.

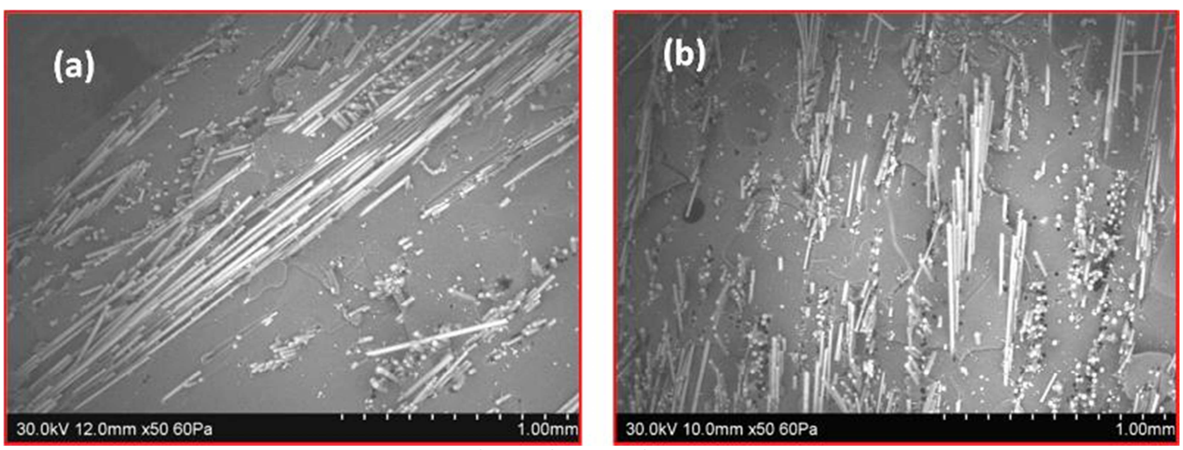

Figure 4: Fractographs of glass fiber reinforced epoxy matrix composite

5. CONCLUSIONS

The glass fibre reinforced epoxy matrix composite was successfully fabricated by using Filament Winding technique. The plane strain fracture toughness of the composite is nearly 40 magnitudes higher in longitudinal orientation in comparison to transverse orientation of fibers. Thus the composite showed an appreciable influence of fiber orientation. These properties obtained from the glass fiber reinforced epoxy matrix show that it is clearly suitable for applications, where the exceptionally high values of longitudinal plane strain fracture toughness can be exploited.

REFERENCES

[1] Chandra Shekar, K., Singaravel, B, Anjaneya Prasad, B and Eswara Prasad, N. 2019, Effect of CNTs addition on the fracture behaviour of neat epoxy and epoxy-carbon fiber reinforced composites, AIP Conference Proceedings, 2057, 020043: DOI: 10.1063/1.5085614

[2] Yong X. Gan. 2009. Effect of interface on mechanical properties of advanced composite materials J of Mol.sci: 54(3):5115-5134.

[3] Sudhir kumar saw, Gautam Sarkhel, and Arup Choudhury. 2011. "Dynamic Mechanical Analysis of Randomly Oriented Short Bagasse/Coir Hybrid Fiber-Reinforced Epoxy Novolac Composites". Springer, Fibers and Polymers 12 (4): 506-513.

[4] Chandra Shekar K, Anjaneya Prasad B, and Eswara Prasad N. 2016. Strengthening In and Fracture Behaviour of CNT and Carbon Fibre Reinforced, Epoxy-Matrix Hybrid Composite". Sadhana, 41(12): 1443-1461

[5] Chandra Shekar. K, Sai Priya. M, Subramanian. P.K, Anil Kumar, Anjaneya Prasad. B and Eswara Prasad. N , 2014. Processing, structure and flexural strength properties CNT and Carbon Fiber Reinforced Epoxy

matrix hybrid Composite. Bulletin of Materials Science, 37(3): 597-602.

[6] Alexopoulos ND, Bartholome C, Poulin P, Marioli-Riga Z. 2010 Structural health monitoring of glass fiber reinforced composites using embedded carbon nanotube (CNT) fibers. Composite Science Technology,70:260–71.

[7] Yaping Z, Aibo Z, Quinghua C, JiaoxiaZ, Rongchang N. 2006, Functionalized effect on carbon nanotube/epoxy nano-composites. Material Science Engineering A, 435–436:145–9.