C. Venkateshwar Reddy Journal of Engineering Research and Application www.ijera.com
ISSN : 2248-9622, Vol. 8, Issue 7 (Part -III) July 2018, pp 21-24

RESEARCH ARTICLE OPEN ACCESS

Mechanical Characterization of Carbon/Epoxy Unidirectional and Bidirectional Composites for Structural Application

C. Venkateshwar Reddy[1], Ch. Joseph S Raju[2], P. Ramesh Babu[3], R. Ramnarayan[4]
[1]Matrusri Engineering College, Hyderabad-500059, India,
[2,4]Advanced Systems Laboratory, Hyderabad-500069, India.
[3]University college of Engineering, Osmania University, Hyderabad, India.
Corresponding author:C. Venkateshwar Reddy

ABSTRACT
Advanced composites are widely used for structural application due to their high strength to weight ratio and other characteristic properties. PAN Carbon roving/Epoxy (UD) and PAN Carbon fabric/Epoxy (BD) composites are being used in structural application based on their engineering properties. To design composite components using these materials a thorough experimental characterization on mechanical properties is prerequisite. In this work, PAN Carbon roving/Epoxy UD laminates were fabricated by filament winding technique and PAN Carbon fabric/Epoxy BD laminates were fabricated by hand lay-up followed by compression moulding technique. Specimens were prepared as per ASTM standards and tested for their Physical and Mechanical properties. Statistical analysis carried out on standard deviation and coefficient of variance was calculated for mechanical properties. Data generated is falling within the accepted levels and the data obtained from various tests are appropriately reduced to evaluate composite material properties that can be used for design and analysis of structural composite components.

Key words- Advanced composites, engineering properties, UD laminates, BD laminates, filament winding technique, compression moulding technique, coefficient of variance

---

Date of Submission: 10-07-2018 Date of acceptance: 24-07-2018

I. INTRODUCTION

Carbon fibre reinforced polymers (CFRP) are widely used in structural applications due to advantages like high specific properties and good damage tolerance [1-2]. Polymeric composites reinforced with carbon exhibit excellent mechanical properties than the conventional metallic materials. The performance of these composites during use is mainly related to their mechanical properties and thermal resistance as a result of combination of reinforcement, polymeric matrix and processing technique [3-5]. Carbon fibre composites, particularly those with polymeric matrices, have become the dominant advanced composite materials for structural application. Since polymer matrix composites combine a resin system and reinforcing fibres, the properties of the resulting composite material will depend on the properties of the fibre, resin, the ratio of fibre to resin in the composite (Fibre Volume Fraction), the geometry and orientation of the fibres in the composite and also on process technique in which the composite is fabricated. The filament winding process is an efficient and viable technique used for the production of monolithic structural advanced fibre reinforced composites such as pressure vessels, pipes and cones [6-8]. In this process structural properties of composite are very good since straight fibres can be laid in a complex pattern. Filament wound parts, in special, attract much attention of the aerospace field and other strength critical applications like high-pressure vessels, commonly applied in rocket motor cases, fuselages, and other structural parts of aircrafts. Hand lay-up followed by compression mould technique is suitable for complex structural parts, in which component is cured out of autoclave.Among the polymeric matrices, the epoxy resins are usedfor structural application, because they generally attend the mechanical strength, chemical resistance and service temperature requirements. The epoxy resin also allows modifications in its chemical structure depending on the required application. In order to design the structural composite products thorough characterization of composite material is prerequisite. The objective of composite material characterization is to the determination of material properties through tests conducted on suitably designed specimens. Characterization is essentially determination of all effective properties over sufficiently large volumes to represent composite and which are statistically reproducible. Since there are more independent material properties for composite materials, it is necessary to obtain more different types of data and also due to scattering in test data more number of specimens are to be tested for design and analysis.

In this work, PAN carbon roving/epoxy UD laminates were made by filament winding technique and PAN carbon fabric (8-harness satin)/epoxy BD laminates were made by hand lay-up followed by compression mould cure technique.

II. EXPERIMENTAL

2.1 Materials

The diglycidyl ether of bisphenol-A (DGEBA) type epoxy resin (epoxy content 5.3 eq/kg), Hardener diethyltoluenediamine (DETDA) was used as a matrix.Carbon fibre T-300 equivalent having a filament diameter of 7µm, tensile strength of 3.4GPa, modulus of 230 GPa with an elongation of 1.8% was used for the experimental purpose.

2.2 Fabrication Of Unidirectional (Ud) Laminates

Impregnation of the carbon roving was carried out by 4-axis filament winding machine using a flat rectangular plate (as shown in Fig.1). The resin bath was heated to 50^{o}C and resin mix temperature maintained during the wet winding. After filament winding, top and bottom plates were assembled with spacers and the mould was cured by following the cure cycle of 80^{o}C/2hr and 120^{o}C/2hr followed by 160^{o}C/3hr.

Fig.1 Carbon roving/Epoxy UD laminate winding by Filament Winding

2.3Fabrication Of Bidirectional (Bd) Laminates

Impregnation of the carbon fabric was carried out initially to get tackiness for making laminates. Prepreg was cut into 300 x 300 mm pieces and hand lay-up was carried out on a mould (as shown in Fig.2) and the mould was cured under hydraulic press following the above same cure cycle.

Fig.2 Carbon fabric/Epoxy BD laminate by Hand-layup

2.4 SPECIMENS PREPARATION FROM LAMINATES

Specimens were prepared from laminates as per ASTM standards cutting into required dimensions using diamond edge cutting wheel machine. Tabs will assist in getting acceptable type of failure mode in gauge length. Fabric based composites can be successfully tested without tabs. However, tabs are strongly recommended when testing unidirectional materials (or strongly unidirectional dominated laminates) to failure in the fibre direction. Tabs may also be required when testing unidirectional materials in transverse direction to prevent gripping damage. The most consistently used bonded tab material has been continuous E-glass fibre-reinforced polymer matrix materials (woven or unwoven) in a [0/90] laminate configuration. The tab material is commonly applied at 45° to the force direction to provide a soft interface. Other configurations that have reportedly been successfully used have incorporated steel tabs, aluminium tabs or tabs made of the same material as is being tested.

III. RESULTS AND DISCUSSION

Table 1 Physical and Mechanical properties of UD laminate.

Sl. No.	Property	No of specimens	Average value	%CV
1.0	**Physical Properties**			
1.1	Density, g/cc	03	1.53	--
1.2	Fiber volume fraction (V_F). %	03	60	--
2.0	**Mechanical Properties**			
2.1	Longitudinal Tensile Strength (σT_{11})	10	1460	6.21
2.2	Longitudinal Tensile Modulus (E_{11})	10	132.56	5.89
2.3	Major Poison's ratio (ν_{12})	05	0.29	1.45
2.4	Transverse Tensile Strength (σT_{22})	10	24.52	5.24
2.5	Transverse Tensile Modulus (E_{22})	10	7.63	1.78
2.6	Longitudinal Compressive Strength (σT_{11})	10	659.37	7.86
2.7	Longitudinal Compressive Modulus (E_{11})	05	97.96	1.83
2.8	Transverse Compressive Strength(σT_{11})	10	105.45	6.60
2.9	In-plane Shear Strength (τ_{12})	10	42.21	3.79
2.10	In-plane Shear Modulus (G_{12})	05	4.55	3.12
2.11	Inter Laminar Shear Strength (ILSS)	10	52.64	3.48
2.12	Flexural Strength	10	1134.55	4.24
2.13	Flexural Modulus	10	105.55	3.78

Table 2 Physical and Mechanical properties of BD laminate.

Sl. No.	Property	No of specimens	Average value	%CV
1.0	**Physical Properties**			
1.1	Density	03	1.46	--
1.2	Fiber volume fraction (V_F)	03	52	--
2.0	**Mechanical Properties**			
2.1	Tensile Strength (σT_{11})	10	557.52	5.02
2.2	Tensile Modulus (E_{11})	10	77.94	4.32
2.3	Poison's ratio (v_{12})	05	0.29	1.54
2.4	Compressive Strength (σT_{11})	10	295.67	4.87
2.5	Compressive Modulus (E_{11})	05	60.07	5.87
2.6	In-plane Shear Strength (τ_{12})	10	52.98	3.94
2.7	In-plane Shear Modulus (G_{12})	05	5.21	4.21
2.8	Inter Laminar Shear Strength (ILSS)	10	54.32	4.34
2.9	Flexural Strength	10	455.30	5.67
2.10	Flexural Modulus	10	62.50	3.45

For each test average value, standard deviation and coefficient of variation was determined. Composite materials are sensitive for their variability in mechanical properties due to their inherent flaws and non-homogeneities. Material factors that can affect test results include material quality, process technique, curing cycle and specimen preparation. Failure modes are indicative of material properties. Effect of misalignment in UD specimens causing premature splitting and strength reduction, which is not an acceptable failure mode. Full potential of fibre in composite will be realized only in acceptable modes of specimen failure. The tension test on longitudinal specimens are conducted to determine longitudinal and transverse tensile strength, Modulus and Poisson's ratio. Tabs are recommended when testing these specimens to get a proper failure in gauge length. Specimen's preparation and testing was carried out as per ASTM D3039. Longitudinal tensile strength is determined from the ultimate load and modulus is calculated from the stress-strain curve. The major poisons ratio is obtained from lateral and longitudinal strains using rosette strain gauges. Clean-cut failure mode observed in transverse tensile test in gauge length. IITRI fixture was used to test compressive property and it is observedclear shear mode of failure in this test. The test in which shear distortion takes place entirely in the plane of the composite material is in-plane shear test. Specimens are cut in 45^0C maintaining standard dimensions. The properties that are determined through this tests are the shear strengths and shear modulus, which represent interface resin bonding property with reinforcement. Strain gauges are used on specimens to measure strains along the loading direction and perpendicular to it. The in-plane shear modulus is calculated from the stress versus strain curve. Test results indicate that mechanical factors that can affect the test results include physical properties of the composite, specimen's preparation, alignment of test specimen with applied force, speed of testing, parallelism of the grips, grip pressure and type of failure mode. Typical failure modes which are acceptable and not acceptable shown below.

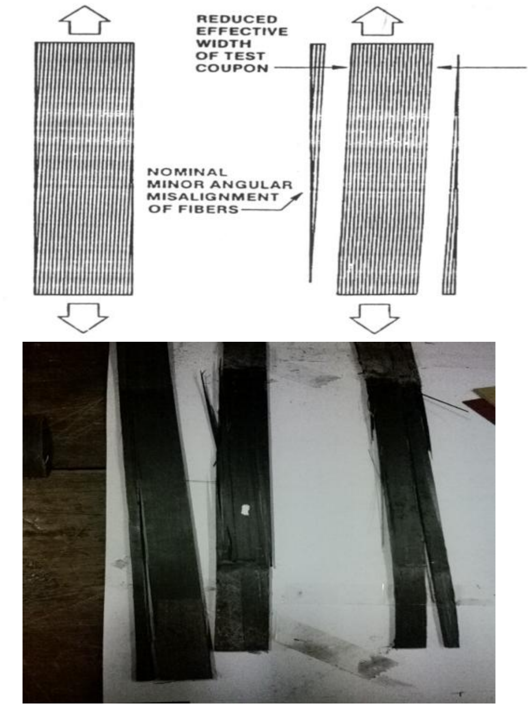

Fig.3: Effect of misalignment in Unidirectional specimens which is not acceptable failure mode.

Misalignment in UD specimens due to improper specimen cutting leads to reduced effective width of test coupon and also angular misalignment of fibres causing premature splitting and strength reduction. Full potential of fibre in composite will not be realised in such type of failure mode.

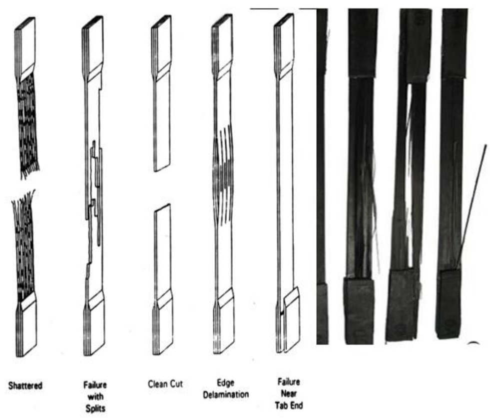

Fig.4: Typical failure modes in straight sided specimens.

By changing the coupon configuration, many of the tensile test methods able to evaluate different material configurations, including UD and BD specimens. Failure of composites unlike metals, a complex multi-stage process. Failure of a composite sample may get triggered in a certain mode, but its propagation and final failure modes are significantly different. In large number of specimens, composite failure gets initiated internally and failure propagate beyond a certain extent.

IV. CONCLUSION

The scope of this composite characterisation was to obtain the engineering properties of carbon fibre reinforced epoxy unidirectional composites manufactured by filament winding and carbon fabric reinforced epoxy bidirectional composites manufactured by hand lay-up followed by compression moulding. Composites are heterogeneous materials and their properties are process dependent. Evaluated physical and mechanical properties of these two materials separately. Mechanical behaviour of the composite material was studied under tension, compression, shear and in bending loads. Mean values, standard deviation and % coefficient of variance were calculated for each mechanical property. Based on this confidence level, the generated data will be useful in design and analysis of composite components for structural application. The data can be useful for numerical simulation studies.Data analysis can be used for calculation of Design allowables required for fabrication of composite products.

REFERENCES

[1]. J.-S. Park, C.-U. Kim, H.-K. Kang, C.-S. Hong, C.-G. Kim. Structural Analysis and Strain Monitoring of the FilamentWound Motor Case. Journal of Composite Materials, 36(20):2373-2388, 2002.

[2]. S. Akbari, F. T. Behrooz, M. M. Shokrieh. Characterization of residual stresses in a thinwalled filament wound carbon/epoxy ring using incremental hole drilling method, Composites Science and Technology, 94:8-14, 2014.

[3]. Jane Maria Faulstich de Paiva, Sérgio Mayer and Mirabel Cerqueira Rezende, 'Comparison of tensile strength of different carbon fabric reinforced epoxy composites', 2006, Journal of Material Research, 9(1).

[4]. Noori Brifcani, Richard Day and David Walker, 'A review of cutting-edge techniques for material selection', 2012, 2nd International Conference on Advanced Composite Materials and Technologies for Aerospace Applications, UK, June 11-13.

[5]. Susanna Laurenzi and Mario Marchetti, 'Advanced composite materials by resin transfer molding for aerospace applications', 2012, Intech, Chapter10.

[6]. F.C. Campbell, 'Structural composite Materials', 2010, Page 141.

[7]. Sohel Rana and Raul Fangueiro, 'Advanced composite materials for aerospace engineering', 2016, Technology & Engineering, pp 147.

[8]. C.Venkateshwar Reddy, P.Rameshbabu, K.Ramaswamy Structural design and analysis of composite rocket motor casing (CRMC) for high strength applications, 2018, JETIR, Volume 5, Issue 6

C. Venkateshwar Reddy "Mechanical Characterization of Carbon/Epoxy Unidirectional and Bidirectional Composites for Structural Application "International Journal of Engineering Research and Applications (IJERA) , vol. 8, no.7, 2018, pp.21-24