

Investigation of bending properties on carbon fiber reinforced polymer matrix composites used for micro wind turbine blades

D.G Puttaraju, H.G.Hanumantharaju, Shreyas, Pradeep, Nuthan

Department of Mechanical Engineering, UVCE, Bangalore, INDIA

Email: puttaraju_dg@yahoo.com

Abstract: Composite is material which is made by two or more constituent material. When these materials are combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. Metallic materials are most widely used in structure, Automobile industry and in our daily life. Metallic materials also show a good property, but main problem with this is more density which causes heavy weight. This is a big disadvantage in many fields. To overcome the problem metallic materials can be replaced by composite material which has lesser density, less weight, higher stiffness, higher strength and better fatigue resistance. The present study is made on Carbon fiber.

Carbon acts a high performance fiber material. It has highest specific modulus and high specific strength of all reinforcing fiber material. Carbon fiber reinforcement composite is a strong, light and very expensive material. High cost of this material is compensated by its excellent strength to weight ratio. The composite consist of Carbon fiber, epoxy resin namely Ly556 and Hardener 951. This study has been done to study the mechanical properties tensile test, compression test, three point bending test etc to be carried out for better understanding of the carbon fiber composite material. In this study three point bending test is discussed and use of carbon fiber and epoxy resin composite in micro wind turbine blade has been studied.

1. Introduction

Wind turbine blade is an important part of the rotor which provides an alternative way of generating energy from the power of wind. Sufficient energy can be produced by making use of wind turbines at windy places where wind speed is so high. The design of blade depends on the extraction of energy and wind turbine blades are designed such that they generate lift from wind and thus rotate. Wind turbine blade design involves material selection, structural configuration, selection of the aerodynamic shape and density of the blade material. To achieve high strength and high modulus requirements, the properties of polymers are modified by using fibers.

In most of the applications, carbon fiber and E-glass fiber are most widely used due to high strength and modulus. Among the thermosetting polymers, epoxy resins are used for high-performance applications, such as matrices for fiber reinforced composites, coatings, structural adhesives and other engineering applications. Epoxy resins are characterized by excellent mechanical and thermal properties, high chemical and corrosion resistance and low shrinkage on curing. The main properties of carbon fiber composites are density-1.518g/cm³, young's modulus-123.34 GPa, poisson's ratio - 0.27, shear modulus-3080, tensile stress-1632 MPa and shear stress - 80Mpa. The present work is related to the development of micro wind turbine blade, blades are one of the most critical components of wind turbine, the carbon fiber / Epoxy composite is selected for the construction of the blade as it is less expensive compared to other fibres.



2. Methodology and experimental procedure

The objective of this experiment is to investigate the behaviour of carbon/Epoxy Composite material specimens under a bending test. This experiment is used to determine the material properties of carbon fiber which is used in a wide range of engineering applications. The aim of the analysis is to validate the bending strength of the micro wind turbine blade by studying the characteristic of a material when subjected to bending load.

3. Manufacturing of composites specimen

Bending test specimen



Fig.1(a) Carbon fiber Lamina



Fig.1(b) Carbon fiber layup in vacuum bagging



Figure 2. Specimen for bending test

4. Fabrication of composites

The specimen for the bending test is a sandwich composite structure, having core made of Balsa wood and the skin is made of 8 layer of Carbon fiber/Epoxy composite. Balsa Wood is the core for the bending specimen. The grain structure of Balsa core is ideal for sandwich construction. It is compatible with all types of manufacturing processes from wet lamination to prepreg construction. The composite consist of carbon fiber, epoxy resin namely Ly556 and Hardener 951. The skin core (Carbon/Epoxy) contains 8 layers and orientation that wrap the central balsa core is shown in the **Table-1**.

Table 1. Layup and Orientation

1 st layer (top layer) – UNID fibres	0 degree
2 nd layer – UNID fibres	0 degree
3 rd layer – UNID fibres	+ 45 degree
4 th layer – UNID fibres	- 45 degree
Central Balsa Wood Core	-
5 th layer – UNID fibres	+ 45 degree
6 th layer – UNID fibres	- 45 degree
7 th layer – UNID fibres	90 degree
8 th layer (Bottom layer) – UNID fibres	90 degree

Hand lay-up technique is used for fabrication of the composite specimen at room temperature. The required ingredients of resin and hardener are mixed thoroughly in a basin and subsequently the mixture is stirred constantly. Carbon fibres are positioned in the open mould and mixture so made is placed uniformly over the glass plies. Then the vacuum bag is mounted on the mould and vacuum bag molding helps to eliminate excess resin that builds up when structures are made using hand lay-up techniques. Atmospheric pressure exerts a force on the bag. The pressure on the laminate removes entrapped air, excess resin, and compacts the laminate resulting in a higher percentage of fiber reinforcement. The prepared sandwich composite materials were taken out from the mould and then specimens of suitable dimensions were prepared for three point bending tests according to ASTM standards. The test specimens were cut using water jet cutting machine. Four identical test specimens were prepared for three point bending test. The carbon fibres provides high strength and stiffness and their modulus of elasticity may be greater than that of the plastic.

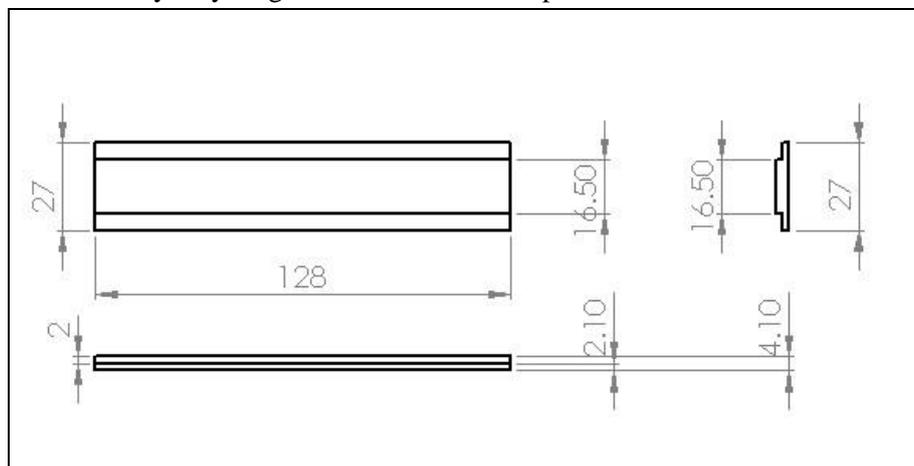


Fig 3. Bending test specimen drawing

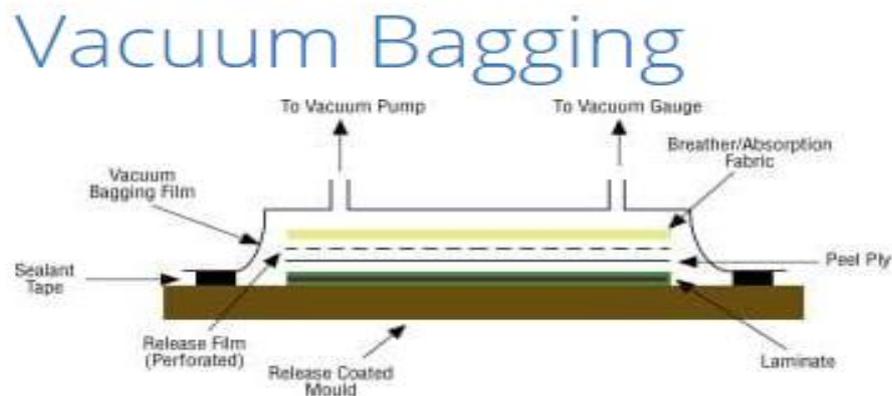


Figure 4. Manufacture of Carbon Fibre using Vacuum process

Resin LY556 and hardener HY951 is used for bonding the bonding the laminate. Carbon fiber with the core of balsa wood is kept and layer by layer carbon fiber is placed along with the epoxy resin and left for hardening at the temperature of 120 degree temperature and allowed to set and then vacuum bagging is done entire thing is covered with the plastic bag placed with the breather and porous sheet and through the vacuum pump air is removed from it to a great extent breather absorbs the excess of resin and air through the porous sheet from the carbon fiber.

Water is pumped at high pressure with 200 to 800 MPa using intensifier technology. An intensifier works on the principle of pressure amplification using hydraulic cylinders of different cross sections. This beam of water is ejected from the nozzle, cutting through the material by spraying it with the jet of speed 1000 m/s with 200 to 800 MPa pressure. Such high velocity water jet can machine thin sheets / foils of aluminium, leather, textile etc.

5. Bending testing

Universal testing machine (UTM) is used for testing the bending strength of carbon fiber composite specimen. A movable cross head moves up and down at a constant speed either using servo-hydraulic system or electromechanical system. UTM with electromechanical system is used for carrying out bending test of the specimen and machines having a computer for analysis and obtain output of the results.



Figure 5. Water Jet Machining



Figure 6. Three point bending Arrangement

The specimen is placed on the rectangular cross section which is rests on two supports and is loaded by means of loading nose midway between the supports. The specimen is deflected until rupture occurs in the outer surface of the test specimen or until a maximum strain of 5.0% is reached. Bending test is carried on four test specimens.

6. Results

Results obtained from this experimental work are presented in Tables 2 and Figures7. Mechanical properties of fiber-reinforced epoxy composites are depending on the properties of the constituent materials (type, quantity, fiber distribution and orientation, void content).

TABLE 2. Result from Three point Bending test

Specimen	Thickness (in mm)	Peak Load (in N)	Peak Displacement (in mm)	Break Load (in N)	Break Displacement (in mm)	Strain
1	4.03	765.18	1.926	461.07	4.803	0.032
2	4.03	1098.4	1.57	509.96	4.854	0.081
3	4.06	706.1	1.96	353.052	4.498	0.075
4	3.96	794.4	4.498	470.73	8.494	0.142

**Figure 7.** Three point bending Test Result

7. Conclusion

This experimental investigation of mechanical behaviour of sandwich carbon fiber/Epoxy composite with Balsa wood core leads to the following conclusions:

- This work shows that successful fabrication of sandwich carbon fiber/Epoxy composite with Balsa wood core which can be used for making micro wind turbine blade and very cost effective by simple hand lay-up technique.
- It was found that the peak load varies from 362.9N to 510.0 N,
- The bending strength of polyester resin has been improved by a great extent due to the presence of carbon fiber reinforcement.

References

- [1] Akhil p Mathew, Athul S, Barath P and Rakesh S: Structural analysis of composite wind turbine blade, 2018
- [2] A.Saha, P.C Roy, N.Modak : Three point bending test of fiber reinforced particulate composites, 2016
- [3] G.velumurugan, S.P.Venkatesan, N.Sathishkumar, N.Vijayakumar Mechanical testing of hybrid Composite material (sisal and coir), 2014
- [4] Mir Ahmed Ali Mujahid, Dr.M.Manzoor Hussain Experimental testing and investigation of Hybrid Fiber reinforced composite, 2017