Study and Analysis of the Mechanical Properties of Carbon/Epoxy Composites used for Automobile Wheel Application

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***Abstract*— Metallic components which are widely used in avionics, civil structures, automobile are been replaced with the aid of composite materials. It is all because of its strength and also due to stiffness-weight ratio. Compared to particular metals, advanced composites have greater arduousness and good strength but with lesser density. Predominantly as in ceramic materials, the main deprivation is their property of brittleness and lower fracture toughness. After all composite materials have been extensively used for various technical and structural tasks, where it should be lighter in weight but should have gigantic strength and stiffness property. Composite assisted by fiber is apparently used form of material in structural utilization. Majority composites consists two phases. One is termed as discrete phase reinforcing material which may be either fiber or flakes and the other is continuous phase where matrix material shares a major part of composite. The major difference between composite material and the alloy is that the constituents will retain their properties and identity after being embedded. Usually composite may be defined as a special structure that is formed by reinforcing matrix and fiber where the function of fiber may be to withstand the load and enhance the stiffness property and matrix binds the fibers firmly.**

In this study, the polymer fiber reinforced composite materials which is one of the alternative material for wheel manufacturing is tested for tensile and compressive test.32 piles of quasi-isotropic oriented composite materials were prepared using hand lay-up method according to the ASTM standards and mechanical properties were observed. An excellent tensile property was observed in length wise direction and adequate compression strength in the oblique direction.

***Keywords*—Composites, stiffness-weight ratio, alloy, quasi isotropic, hand layup method.**

I. INTRODUCTION

Composite material are formed when two or more materials are combined on a macroscopic scale to form a useful material. The upheld property of composite is, they exhibit the superior qualities of their ingredients and also some features that neither constituent possesses. Compared to distinct metals, avant-grade composites have greater wearisome and better durability but with smaller density [1, 2]. These resources make advanced composites extremely striking and purposeful in circumstances where element weight is censorious. Composites are made from fibers which are mainly obtained from natural or man-made sources. Composies are mainly classified as Polymer matrix composites, Ceramic matrix composites and Metal matrix composites. In recent days the composites are obtaining large application in many fields namely the Aviation, Automobile sector, defense, marine applications. Due to their unique properties namely the lighter in weight, flexibility for design, stability in dimensions, stronger when compared to other metallic materials, good resistance to high temperature and corrosion, and also a very good mechanical strength they are gaining the greater application in automotive sector [3, 4]. Many parts of an automobile are being manufactured using the composite material because of their enumerable properties. In this study the carbon/epoxy composites which can be used in an automobile wheel is manufactured and certain tests are carried out. Thus prepared 32 piles of composites were undertaken tensile and compressive tests were done both in longitudinal and the transverse direction.

II. LITERATURE REVIEW

Bao Y, et al.conveyed "Research of lightweight composite automobile wheel" [5]. In this study, carbon/epoxy (T300/5222) composite materials were subjected to the radial, bending and impact load. Further the Carbon/epoxy composite wheel was compared with the wheel of same dimension but made of aluminium material. They concluded that there was about 11.3%reduction in weight when compared to the aluminium wheel.

Jyothi studied "Advanced vehicle performance by replacing a conventional vehicle wheel with a carbon fiber reinforced composite". The study was based on reducing the weight of the wheel, rotational inertia and unsprung mass by using the carbon/epoxy based composite material.it was found that about 40-50%of weight was reduced when compared to that of the conventional wheels.

Jakubczak, et al. conducted "carbon fiber reinforced wheel for ultra-efficient vehicle". Study included the manufacturing method used, innovative design and the test that have been done on the wheel that is being used in vehicle and the result was tabulated saying that there was about 40% reduction in the weight by using CFRP material based composite.

Choudhury DR investigated "Design and analysis of composite wheel rim" . Study was based on the comparison of aluminium alloy based wheel with that of the cabon/epoxy composite wheel. Numerical analysis was done by using the

ANSYS workbench and was concluded that carbon/epoxy based wheel was having the greater tendency to improve the performance of the FSAE vehicle.

Eneyw Gardie, et al. investigated "Study on the Mechanical Characterization of Composite Materials for Automotive Wheel Application"[12].The work reflected the tabulation of tensile and the compressive strength of the carbon/epoxy based composite material wheel where is was observed that good tensile property was observed in longitudinal direction and moderate compressive strength was observed in transverse direction.

III. MATERIALS AND FABRICATION

The materials that have been used in this study includes:

1) Fiber (Carbon fiber)

2) Matrix (Epoxy resin)

3) Hardener

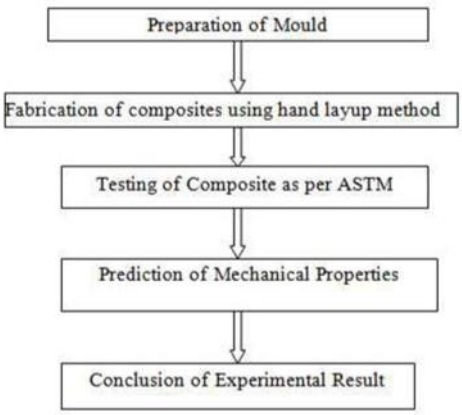
A. Materials

The reinforcement or the fiber used here is carbon fiber and the matrix used here is the epoxy resin which is blended together in 60% and 40% to form a composite material.

Epoxy resin, which is normally used as binding agent exhibits poor mechanical and thermal property. To enhance the property the resin is made to undergo curing reaction where linear chain of epoxy gets converted into 3D cross linked chain. This gets achieved by the addition of curing agent termed as Hardener which is to be added in ratio of 1:10 to the resin.

B. Fabrrication

The fabrication process used here is the Hand Layup method. The mould is filled with the mixture of fiber and matrix and constant pressure is applied in all the directions. Thus obtained composite slab is machined for appropriate dimensions according to the ASTM standards for tensile and compressive test.



Methodology of work

IV. RESULTS

Carbon/epoxy composites thus prepared was machined according to the dimensions of ASTM standards for the tensile and compression tests and the test was carried out in the universal testing machine.

A. Tensile Test

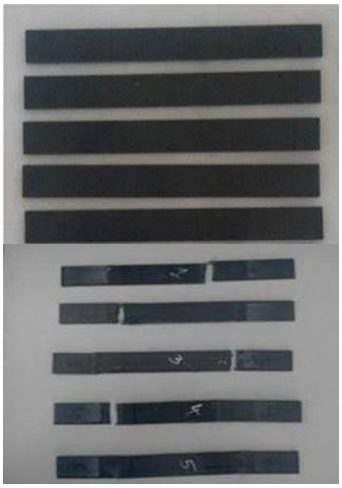


Fig 1: Specimen before tensile test and after tensile test

Figure 1 represents the standard size of the specimen before conducting the tensile test and the test specimen after conducting the tensile test in longitudinal direction.

Sl.No	*Properties*	*Symbol*	*Value*	*Unit*
1	Density	ρ	1.524	g/cm^3
2	Tensile strength in X direction	σ_{tx}	1.283	Gpa
3	Tensile strength in Y direction	σ_{ty}	0.295	Gpa
4	Tensile strength in Z direction	σ_{tz}	1.283	Gpa

Table 1: Calculated tensile property of carbon/epoxy composite materials

Table 1 shows the calculated values of density, tensile strength in X, Y, Z directions respectively.

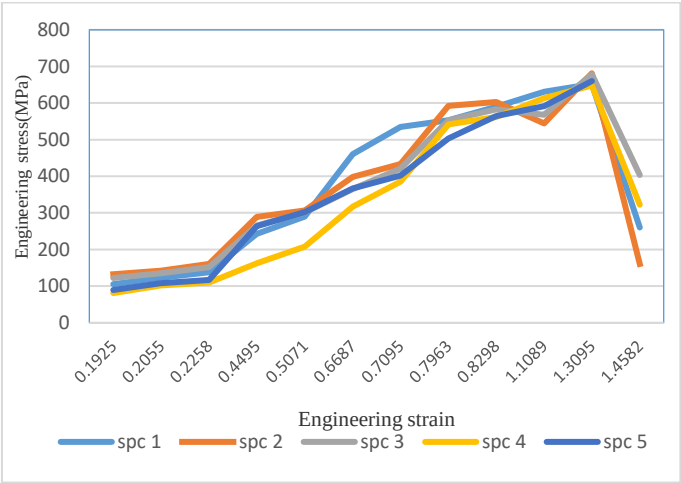


Fig.2: Engineering stress-strain graph for longitudinal tensile specimens

Fig 2 indicates the stress-strain curve for the specimens that have been tested for the tensile property. From the curve it is

observed that the stress-strain behavior for the tensile strength goes on increasing linearly and then final failure occurs. The maximum load applied on the specimen was 59.99KN and the maximum tensile strength was found to be 692.36MPa.

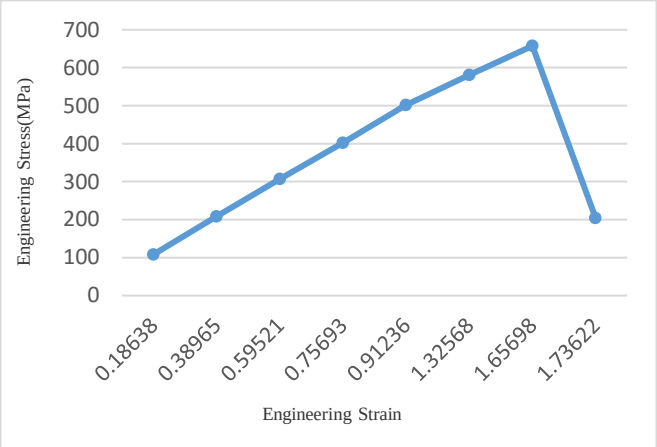


Fig.3: Average Stress-Strain graph for longitudinal tensile testing

Fig.3 shows the average stress strain curve for the tensile testing specimens in the longitudinal direction where the maximum load applied on the specimen was 59.99KN. In this figure, engineering stress increased linearly with an increase in engineering strain until the ultimate load point with the application of tensile loading in uniaxial direction.

B. Compressive test

Carbon/epoxy composites prepared using the hand layup method was machined as per the ASTM standards for the compressive test and the test was done in the universal testing machine.

Sl.No	*Properties*	*Symbol*	*Value*	*Unit*
1	Compressive strength in X direction	σ_{cx}	0.683	Gpa
2	Compressive strength in Y direction	σ_{cy}	0.339	Gpa
3	Compressive strength in Z direction	σ_{cz}	0.683	Gpa

Table 2: Calculated compressive property of carbon/epoxy composite materials

Table 2 shows the calculated values of compressive property in X, Y, Z directions respectively.

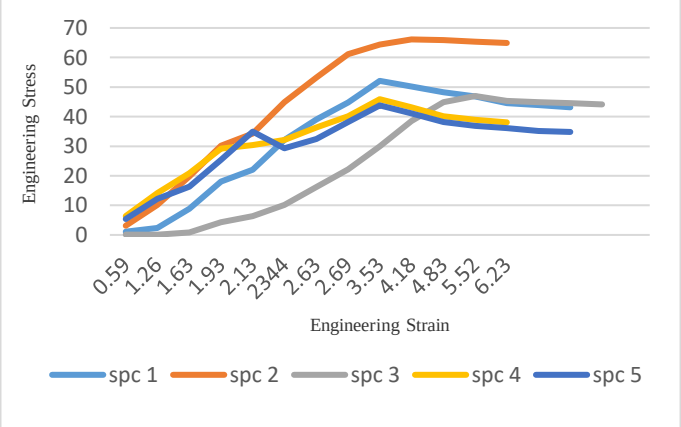


Fig.4: Engineering stress-strain graph for transverse compressive property

Fig.4 shows the stress strain curve for the various specimens under the compressive loading in the transverse direction. The compressive strength increased linearly with the increase in the compressive load and finally it failed after exceeding the ultimate compressive strength.

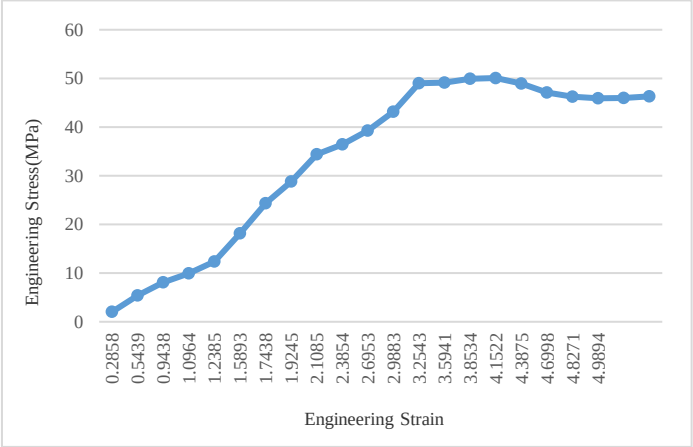


Fig.5: Average Stress-Strain graph for transverse compressive testing

Fig.5 shows the average compressive stress-strain curve for the carbon/epoxy composite material in the transverse direction. The maximum compressive load applied was 20KN and the maximum transversal compressive strength was found to be 248.33 MPa.

CONCLUSION

In this present study the Carbon/epoxy based composite material was fabricated using the hand layup method.

1. Composite material was machined according to the ASTM standards for tensile and compressive tests. The test was carried out in the UTM machine and the mechanical properties was obtained from its records.
2. The result obtained reflected that the carbon/epoxy composite material exhibited enormous tensile strength in the longitudinal direction and the moderate compressive strength in the transverse direction.
3. In this work it was observed that the propagation of the failure occurred in the matrix layer at the beginning and then the damage was observed in the fiber layer and thus the propagation of failure moved from layer to next layer.
4. It was also observed that as the number of layers of laminates goes on increasing there was enhancement in the mechanical properties.
5. The mechanical property was found to be dependent on the thickness of the fiber and its orientation.

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