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Design and Experimental Investigation of Composite Automotive Drive Shaft

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Abstract: Replacing composite bodies by the conventional metallic bodies have many advantages because of high specific strength and high specific stiffness of the composite materials. As compared to the conventional drive shafts, Composite drive shafts have the potential of lighter and longer life with high rotational speed. Nowadays drive shafts are used in two pieces. However, the main advantage of the current design is that only one piece of composite drive shaft is possible that fulfils all the drive shaft requirements. The torsional strength, torsional buckling and bending natural frequency are the main basic requirements considered here. This work is all about the replacing the conventional two-piece steel drive shaft with a one-piece carbon/epoxy. Design of composite drive shaft Classical Lamination Theory is used for the design of composite drive shaft. Finite element analysis (FEA) was used to design composite drive shafts incorporating carbon within an epoxy matrix. From experimental results, it was found that the developed one-piece automotive composite drive shaft had 64% mass reduction, 74% increase in torque capability compared with a conventional two-piece steel drive shaft. It also had 6380 rpm of natural frequency which was higher than the design specification of 3050 rpm.

Index Terms: Bending frequency, Composite Materials, Drive shaft, Finite Element Analysis (FEA), Power transmission, Torsion, Torsional buckling.

I. INTRODUCTION

A. Project Background

An automotive drive shaft is used to transmit the power from the engine to the differential gear of a rear wheel drive vehicle as shown in below Fig. [1]. The minimum drive shaft torque capability required is 3500Nm for passenger cars and the minimum fundamental bending natural frequency required is 9200 rpm to avoid whirling vibration [2]. When the length of drive shaft is about 1.5 m, the bending natural frequency is normally lower than 5700 rpm of a one piece drive shafts (made of steel or aluminum). In order to increase the fundamental bending natural frequency the steel drive shaft is usually manufactured in two pieces, because the bending natural frequency of a shaft is directly proportional to the square root of specific modulus and inversely proportional to the square of beam length.

The two-piece steel drive shaft requires 3 universal joints, a bracket & a centre supporting bearing, which increases the total automotive vehicle weight and decreases fuel efficiency. The specific stiffness (E/ρ) of carbon fibre epoxy composite materials is more than four times than that of steel or aluminium materials, hence it is possible to manufacture one-piece composite drive shafts without whirling vibration over 9200 rpm.

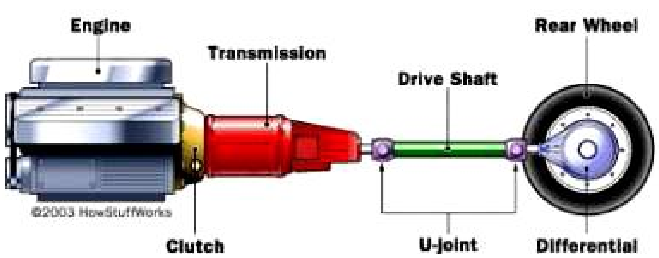


Fig -1: Schematic arrangement of Propeller shaft

The major benefits of composite drive shaft are reduced weight, less noise and vibration. However, because of the high material cost of carbon fibre epoxy composite materials, rather cheap aluminium materials may be used partly with composite materials such as in a hybrid type of aluminium/composite drive shaft, in which the role of aluminium is to transmit the required torque, while the carbon fibre epoxy composite increases the bending natural frequency above 9200 rpm. However, the hybrid drive shaft needs reliable joint between the hybrid shaft and steel yoke of a universal joint, which is always the most difficult task.

B. Classification of Composites

Composite materials are categorised based on reinforcements or the surrounding matrix. They are as follows:

1) Fibrous composite materials which consist of fibres in a matrix.
2) Laminated composite materials which consist of layers of various materials.
3) Particulate composite materials which are composed of particles in a matrix.
4) Combinations of some of first three types or all of the first three types.

And classification of composites based on structural composition of the matrix are as follows

a) Polymer-Matrix Composites
b) Metal- Matrix Composites
c) Ceramic- Matrix Composites
d) Carbon- Carbon Composites
e) Hybrid Composites

C. Advantages of Composites over the Conventional Materials

1) High strength to weight ratio
2) High stiffness to weight ratio
3) Better fatigue resistance
4) High impact resistance
5) Good thermal conductivity
6) Improved corrosion resistance
7) High damping capacity.

D. Limitations of Composites over the Conventional Materials

1) They have more complex mechanical characterization than that of metallic structure
2) The design of fibre reinforced structure is difficult compared to a metallic structure, mainly due to the difference in properties in directions
3) They have high fabrication cost
4) Rework and repairing are difficult.

E. Applications of Composite Materials

1) *Automotive :* Drive shafts, clutch plates, leaf springs, suspension arms, bearings for steering system, bumpers, body panels and doors
2) *Aerospace:* Drive shafts, elevators, landing gear doors, panels and floorings of airplanes, payload bay doors etc.
3) *Marine:* Propeller vanes, gear cases, fans & blowers, valves & strainers, condenser shells.
4) Chemical Industries

F. Problem Statement & Project Objectives

Almost all automobiles have transmission shafts. The weight reduction of the Propeller shaft can play a certain role in the total weight reduction of the vehicle. In order to reduce the fuel consumption & to increase the natural frequency of the shaft it is possible to achieve composite drive shaft design with less weight. By doing the same, it also maximize the torque transmission capacity and torsional buckling capability

The main project objectives are:

1) To minimize the weight of composite drive shaft as compared to steel shaft.
2) To study the effect on torsional buckling strength of composite of drive shaft with respect to-:
a) Fiber orientation
b) Stacking sequence of laminates
3) To increase the torsional buckling strength of composite drive shaft.

II. FINITE ELEMENT ANALYSIS

Finite element analysis is a computer based analysis software for calculating the strength and behavior of structures. The FEA is also used to calculate the deflection, stresses, strains temperature, buckling behavior of the member. In our project FEA is carried out by using the ANSYS 14.5.

General procedure of FEA is as follows:

1) Selection of suitable variables and elements.
2) Discretization of continua.
3) Selection of interpolation functions.
4) Finding the element properties.
5) Assembling element properties to get global properties.
6) Imposing the boundary conditions.
7) Solving the system equations to get the nodal unknowns.
8) Making additional calculations to get the required values.

A. Static Analysis

A static analysis is mainly used to find the displacements, stresses, strains and forces in components or structures when external loads are applied. The steady inertia loads such as gravity, time varying loads, spinning etc. can also be included in a static analysis. Response conditions are to be assumed in static analysis loading i.e. with respect to time the loads and the structural responses are assumed to vary slowly. The types of loading in static analysis includes, externally applied forces, pressures & moments. If the stress values obtained in this analysis exceeds the allowable values it will result in the failure of the structure in the static condition itself. So this analysis is necessary in order to avoid such a failure.

Static Analysis of Composite Drive Shaft

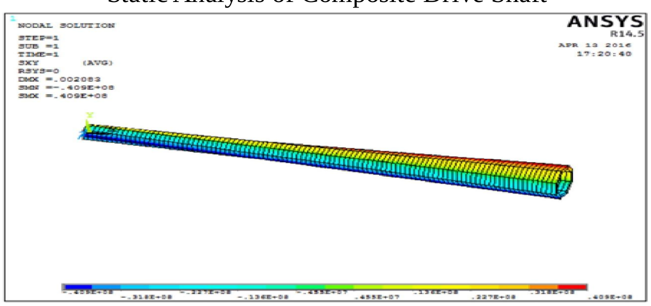


Fig -2: Maximum shear stress in the composite drive shaft

The above image shows shear stress value with the help of color bar. The value ranges on object are determined using color bar. Maximum shear stress in the composite drive shaft is 40.93 MPa which are within permissible limit.

Static Analysis of Steel Drive Shaft

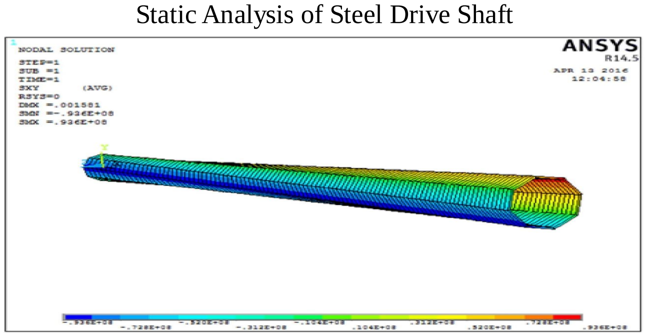


Fig -3: Maximum shear stress in the steel drive shaft

The above image shows shear stress value with the help of color bar. The value ranges on object are determined using Color bar. Maximum shear stress in the steel drive shaft is 93.62 MPa which are within permissible limit.

B. Boundary Conditions

The finite element model of HS Carbon fiber / Epoxy shaft as shown above has one fixed end and at the other end torque is applied. The torque of 1352 N-m (for carbon shaft and steel shaft) is applied at the other end which is free.

Table -1: Material Properties of Steel and Carbon fiber/ Epoxy Drive Shaft

Sr. No.	Property	Steel	Carbon Fiber/ Epoxy
1	Young's Modulus X Direction	2.07e11	47.05e9
2	Young's Modulus Y Direction	-	58.64e9
3	Young's Modulus Z Direction	-	58.64e9
4	Major Poisson's Ratio XY	0.3	0.3
5	Major Poisson's Ratio YZ	-	0.3
6	Major Poisson's Ratio XZ	-	0.3
7	Shear Modulus XY	-	25.55
8	Shear Modulus YZ	-	25.55
9	Shear Modulus XZ	-	25.55
10	Density	7800	1550.5

C. Finite Element Method Result

Table -2: Finite Element Method Result

Analysis Type	Composite shaft	Steel shaft
	Static Analysis	
Maximum Shear Stress	40.93 MPa	93.62 MPa

III. MANUFACTURING METHODOLOGY

Some of the more popular techniques are:

1) Filament Winding
2) Prepreg and Prepreg Layup
3) Pultrusion
4) Tube rolling

Out of this above four process filament winding method is used in this project work because it has good advantages, such as it consists of a highly automated process, with low manufacturing costs, the rotational speed of the mandrel & the transverse speed of the fiber winding head controls the fiber orientation, and this process is all about controlling the winding tension on the fibers, so that they can be very tightly packed together in order to produce high fiber volume fractions.

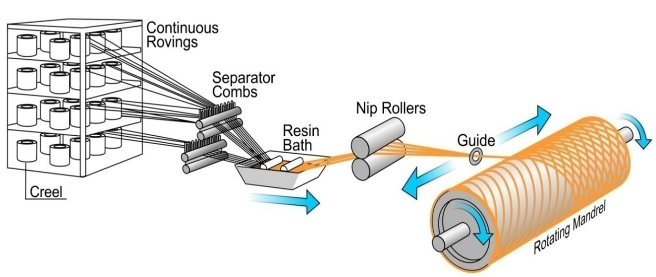


Fig -4: Schematic of filament winding process

A. Filament Winding Manufacturing Step

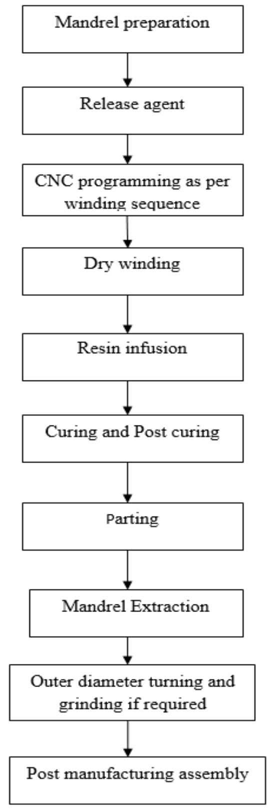


Fig -5: Filament Winding Manufacturing Step

Fig -6: Actual Filament winding process

IV. EXPERIMENTATION

1) The first thing that was done in the lab was the measuring of the diameter of the specimen gauge section using calipers, and to record that value for later calculations.
2) After that, we have drawn a straight longitudinal line on the specimen in order to observe the angle of twist of the specimen during the test.
3) Grip the test specimen on the torsion testing machine with the help of hexagonal sockets firmly mount the test specimen. Fit one end of the test specimen to input shaft and the other end to torque shaft and the torque meter reading is to be set to zero.
4) Start twisting of the test specimen until failure at strain increment of 10. Observe & record the data rotation in the table.
5) Construct & obtain the relationship between shear stress and shear strain. Also determine maximum shear stress, modulus of rigidity and shear stress at proportional limit.
6) Sketch fracture surfaces of failed specimens and describe their natures in the table.
7) Discuss and conclude the obtained experimental results.

Fig -7: Torsion testing setup

Fig -8: Twisted shaft

The above Fig. 8 shows the torsion test setup and twisted carbon fiber/Epoxy shaft. Fig. 7 shows the coupling and connections. In fig. 8 twisted shaft is observed.

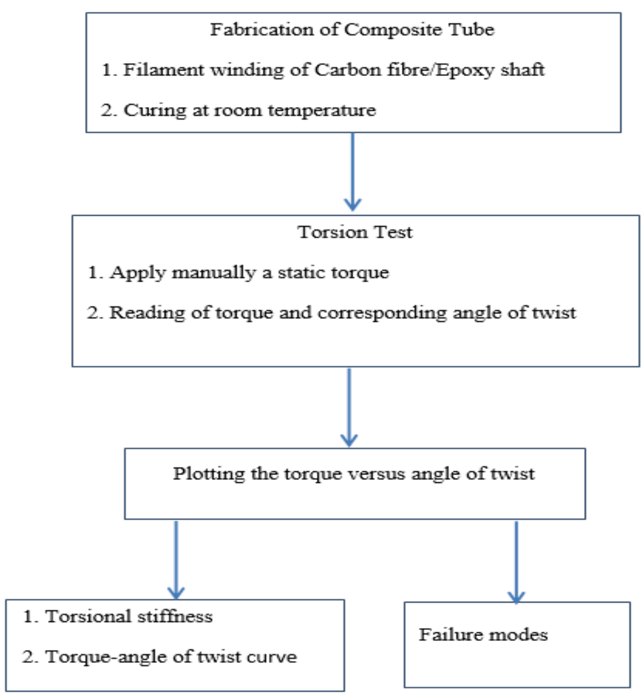


Fig -9: Flow chart of the experimental work

V. RESULTS

The data that was collected during the torsion testing lab was Torque (kg-m), and angle of twist.

A. Plot a graph of applied torque on X-axis against angle of twist on Y-axis for the elastic region
B. Plot a graph of applied torque on x-axis against angle of twist on Y-axis of the specimen, until destruction.

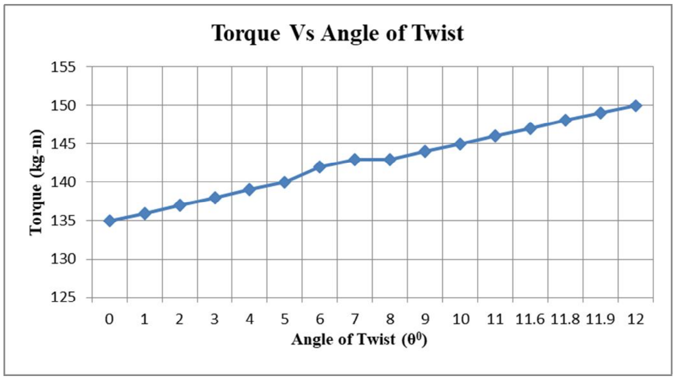


Fig -10: Graph of Torque Vs Angle of Twist

The above results are showing a linear increase in deflection with increasing torque. In this torsion testing we apply torque up to 1500 N-m (150 kg-m) on the composite drive shaft. Here we want to transmit the torque up to 1352.25 N-m and the shaft is slightly twisted at 1500 N-m. Thus theoretically speaking from the graph, the relationship between the applied torque and the angle of twist is complete linear.

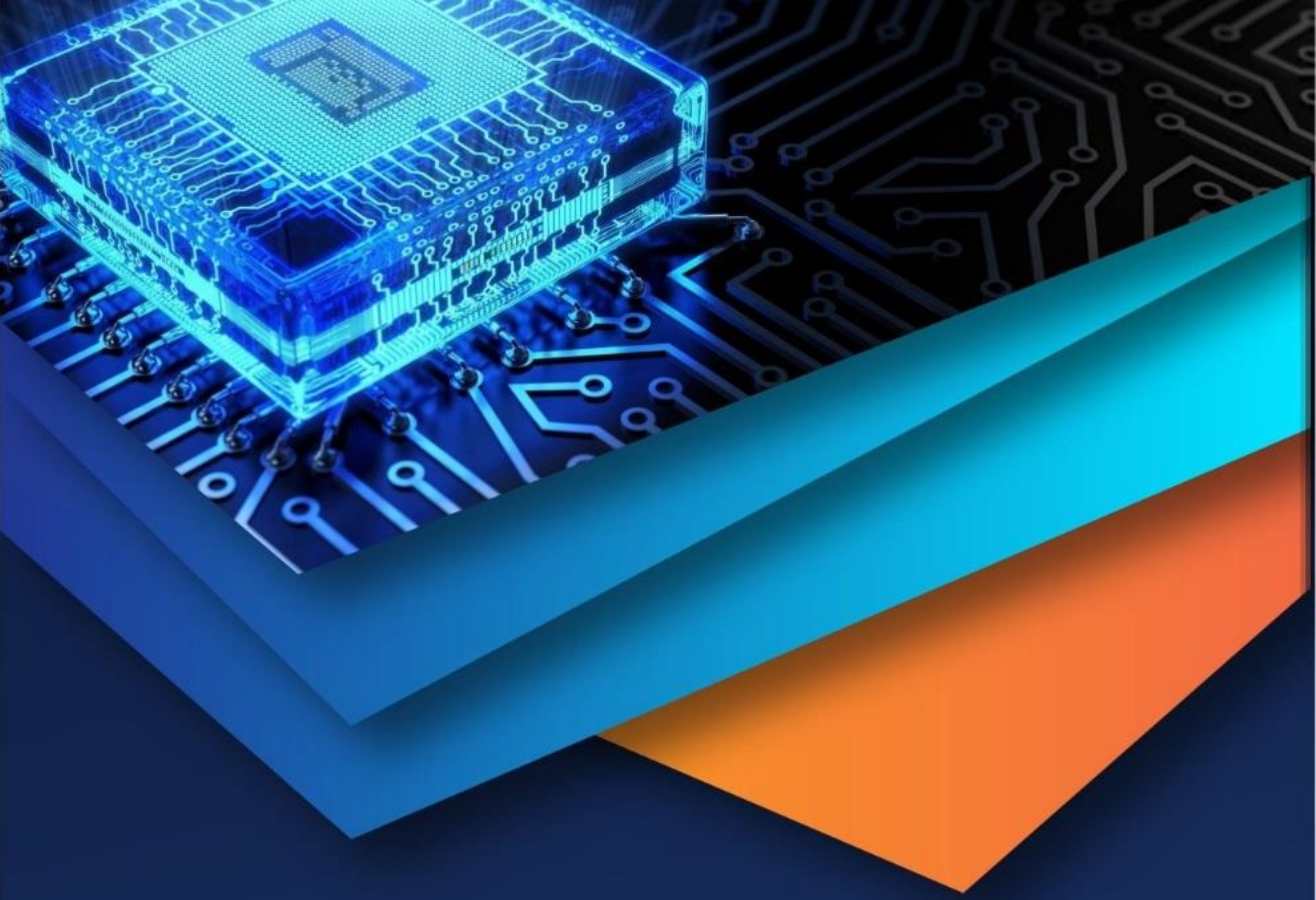
VI. CONCLUSIONS

The following conclusions are drawn from the Present work.

1) The carbon/Epoxy drive shaft has been designed for the replacement of the steel drive shaft of an automobile. By using classical lamination theory a one–piece composite drive shaft has been designed optimally with the objective of weight minimization of the shaft.
2) The weight saving of the carbon/Epoxy drive shaft is 63.13% as compared to steel drive shaft.

REFERENCES

[1] Dai Gil Lee *, Hak Sung Kim, Jong Woon Kim, Jin Kook Kim Design and manufacture of an automotive hybrid aluminum/composite drive shaft, Composite Structures 63 (2004) 87–99.
[2] M.A. Badie, E. Made , A.M.S. Hamouda An investigation into hybrid carbon/glass fibre reinforced epoxy composite automotive drive shaft, Materials and Design 32 (2011) 1485–1500.
[3] S.A. Mutasher, Prediction of the torsional strength of the hybrid aluminum/composite drive shaft, Materials and Design 30 (2009) 215–220
[4] Khalid YA, Mutasher S A, Saharib B, Hamouda AMS. Bending fatigue behaviour of Hybrid aluminum/ composite drive shafts. Mater Des 2007; 28(1):329–34.
[5] Durk Hyun Cho,Jin Ho Choi. Manufacture of one-piece automotive drive shafts with aluminum and composite materials, ComposireShuctum Vol. 38, No. l-4, pp. 309-319, 1997.
[6] O. Montagniera Ch. Hochard b Optimisation of hybrid high-modulus/high-strength carbon fibre reinforced plastic composite drive shafts, Materials and Design 46 (2013) 88–100.
[7] A.R. Abu Taliba, AidyAlib, Mohamed A. Badiea, NurAzidaCheLahb, A.F. Golestanehb Developing a hybrid, carbon/glass fiber-reinforced,epoxy composite automotive drive shaft, Materials and Design 31 (2010) 514–521.
[8] SecilEksi, Akin O. Kapti, KenanGenel, Buckling behaviour of fibre reinforced plastic–metal hybrid-composite beam, Materials and Design 49 (2013) 130–138.



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