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# Design and Analysis of Composite Drive Shaft for Automotive Application

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***Abstract* – Our research work mainly focuses to design and analyses a composite drive shaft for power transmission in automobiles. The composite shaft has high specific stiffness and high specific strength when compared to ordinary steel shaft. In this present work the conventional two-piece steel drive shafts is replaced with a single composite drive shaft. Analysis has been carried out to estimate deflection, stresses under subjected loads & natural frequencies using FEA and the results are compared with steel shaft to validate our project. Substituting composite structures for conventional metallic structures has much advantage because of higher specific stiffness and strength of composite materials. This work deals with replacement of conventional two piece steel drive shaft with a single-piece e-glass/epoxy, high strength carbon/epoxy and high modulus carbon/epoxy composite drive shaft for automobile shaft for an automotive application. The design parameters were optimized with the objective on minimizing the weight of composite drive shaft.**

***Keywords:*** Composite Drive Shaft, Automotive Application, power transmission, strength, stiffness.

## I. INTRODUCTION

### 1.1 Drive Shaft

A driveshaft is a rotating shaft that transmits drive to wheels. Driveshaft must operate through constantly changing angles between the transmission and axle. High quality steel (Steel SM45) is a common material for construction. Steel drive shafts are usually manufactured in two pieces to increase the fundamental bending natural frequency because the bending natural frequency of a shaft is inversely Proportional to the square of beam length and Proportional to the square root of specific modulus [1]. The two piece steel drive shaft consists of three universal joints, a cross center supporting bearing and a bracket, which increase the total weight of a vehicle. Power transmission can be improved through the reduction of inertial mass and light Hook's weight. Substituting composite structures for conventional is metallic structures has many advantages because of higher specific stiffness and higher specific strength of composite materials. Composite materials can be tailored to efficiently meet the design requirements of strength, stiffness and composite drive shafts weight less than steel or aluminum of similar strength. It is possible to manufacture one piece of composite. Drive shaft to eliminate all of the assembly connecting two piece steel drive shaft. Also, composite materials typically have a lower modulus of elasticity.

As a result, when torque peaks occur in the driveline, the driveshaft can act as a shock absorber and decrease stress on part of the drive train extending life. Many researchers have been investigated about hybrid drive shafts and joining methods of the hybrid shafts to the yokes of universal Joints. But this project provides the analysis of the design in many aspects. The advanced composite materials such as Graphite, Carbon, Kevlar and Glass with suitable resins are widely used because of their high specific strength (strength/density) and high specific modulus (modulus/density).Advanced composite materials seem ideally suited for long, power drive shaft (propeller shaft) applications. Their elastic properties can be tailored to increase the torque they can carry as well as the rotational speed at which they operate. The drive shafts are used in automotive, aircraft and aerospace applications [2].

The automotive industry is exploiting composite material technology for structural components construction in order to obtain the reduction of the weight without decrease in vehicle quality and reliability. It is known that energy conservation is one of the most important objectives in vehicle design and reduction of weight is one of the most effective measures to obtain this result. Actually, there is almost a direct proportionality between the weight of a vehicle and its fuel Consumption, particularly in city driving [3].

They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia. To allow for variations in the alignment and distance between the driving and driven components, drive shafts frequently incorporate one or more universal joints, jaw couplings, or rag joints, and sometimes a splinted joint or prismatic joint.

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### 1.2 Different Types of Shafts

*Transmission shaft:* These shafts transmit power between the source and the machines absorbing power. The counter shafts, line shafts, overhead shafts and all factory shafts .Since these shafts carry machine parts such as pulleys, gears etc., therefore they are subjected to bending movement in addition to twisting [4].

*Machine Shaft:* These shaft forms an integral part of the machine itself. For example crank shaft is an internal part of I.C. engine slider-crank mechanism.

*Axle:* A shaft is called "an axle", if it is a stationary machine element and is used for the transmission of tending moment only. It simply acts as a support for rotating bodies.

*Application:* To support hoisting drum, a car wheel or a rope sheave.

*Spindle:* A shaft is called "a spindle", if it is a short shaft that imparts motion either to a cutting tool or to a work-piece.

### 1.3 Problem Description

Stainless steel was mainly used because of its high strength. But this stainless steel shaft has less specific strength and less specific modulus. Stainless steel has less damping capacity. Because of its higher density of molecules of stainless steel, its weight is very high. Because of increase in weight fuel consumption will in increase, the effect of inertia will be more [5]. Because of increase in weight of the propeller shaft we are replacing the stainless steel with the composite materials, which are very less weight when compared to that of stainless steel. The deflection of composite materials is less when compared to that of stainless steel.

## II. SYSTEM DESIGN

**2.1 About Composites:** A material composed of two or more constituents is called composite material. Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and or not soluble in each other. The main difference between composite and an alloy are constituent materials which are insoluble in each other and the individual constituents retain those properties in the case of composites, whereas in alloys, constituent materials are soluble in each other and forms a new material which has different properties from their constituents.

### 2.2 Classification of Composite Materials

- Polymer matrix composites
- Metal matrix composites
- Ceramic Matrix

### 2.3 Comparison of Stainless Steel with Composite Materials

| Property | Stainless steel | Composite materials |
|---|---|---|
| Specific strength | Low | High |
| Specific modulus | Low | High |
| Weight | High | Low |
| Cost | High | Low |
| Corrosion | High | Low |
| Thermal conductivity | Medium | Medium |
| Damping capacity | Medium | High |

## III. METHODOLOGY

Modeling and analysis of 3-Dimensional models of the drive shaft were carried out using catia & solid words and analysis is carried out using Ansys software structural analysis of composite drive shaft and steel drive shaft are carried out. The results are compared with steel shaft to validate our project. Analysis using FEA tool is necessary to standardize the experimental procedures [6].

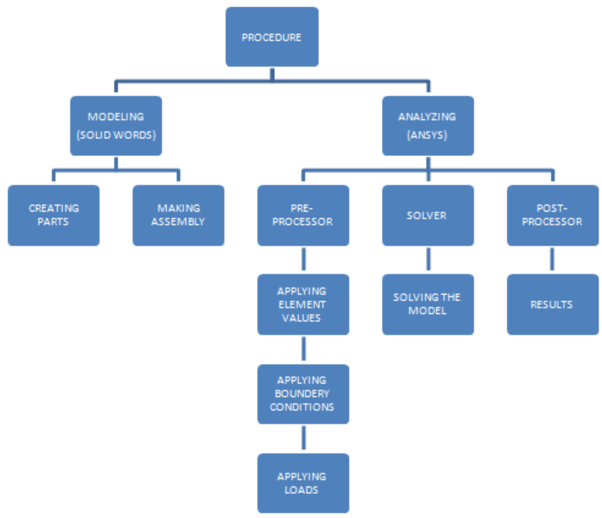


**Figure 1: Flow diagram of methodology**

### 3.1 Conventional Two-Piece Drive Shaft Arrangement

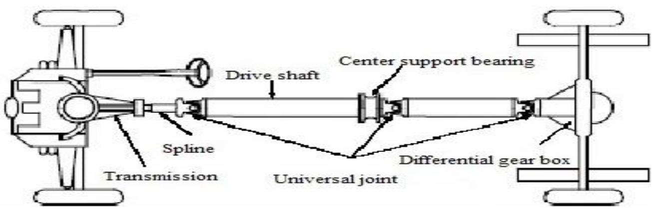


**Figure 2: Conventional Two-Piece Drive Shaft Arrangement**

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### 3.2 Introduction to Drive Shaft

An automotive propeller shaft, or drive shaft, transmits power from the engine to differential gears of rear wheel-driving vehicle. A propeller shaft is an assembly of one or more tubular shaft connected by universal, constant velocity or flexible joints. The number of tubular pieces and the joints depends on the distance between the gearbox and the axle. Composite materials have been widely used to improve the performance of various types of structures. The reduction of the weight without decrease in vehicle quality and reliability. Composite drive shaft has many benefits such as reduced weight and less noise and vibration [7].

### 3.3 Functions of the Drive Shaft

First transmit torque from the transmission to the differential gear box. The drive shaft must also be capable of rotating at the very fast speed required by the vehicle. The drives shaft must also operate through constantly changing the angles between the transmission, the differential and the axels. The length of the drive shaft must also be capable of changing while transmitting torque [8]. A material composed of 2 or more constituents is called composite material. Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents.

## IV. RESULT AND DISCUSSION

ANSYS is an analysis tool which was used by mechanical engineers to check the feasibility of any product before launching into the market. Various analyses can be done before launching the product into the market. Various types of analysis techniques were used among them static, model, buckling, CFD etc.

In this scenario we consider buckling, model, and static analysis by finite element technique. From these analysis techniques we got the following results.

Finite element analysis is a computer based numerical technique is used to for calculating the strength and behavior of the engineering structures. The structure on which the analysis can be done is divided into large number of finite elements and required stress at the desired point can be calculated. The accuracy of the structure depends on the no of finite elements made.

### Applications of FEA

- Structural engineering (analysis of frames, trusses, bridges etc).
- Aircraft engineering (analysis of aero plane wings, different parts of missiles and rockets).
- Heat engineering (analysis on temperature distribution, heat flux etc).
- Hydraulic and hydrodynamic engineering (analysis of viscous flow, potential and boundary layer flows).

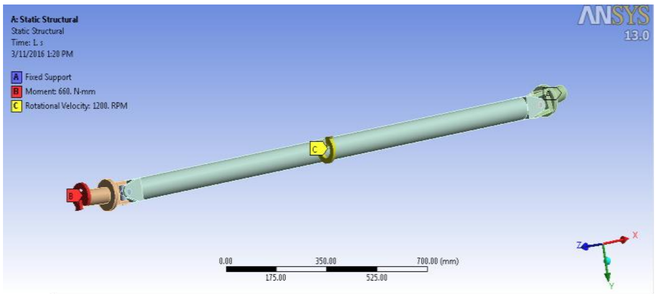


**Figure 3: Analysis of Static Structural**

### 4.1 Structural Analysis

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

*Static Analysis:* Used to determine displacements, stresses, etc. under static loading conditions. Both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

*Modal Analysis:* Used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available.

*Harmonic Analysis:* Used to determine the response of a structure to harmonically time-varying loads.

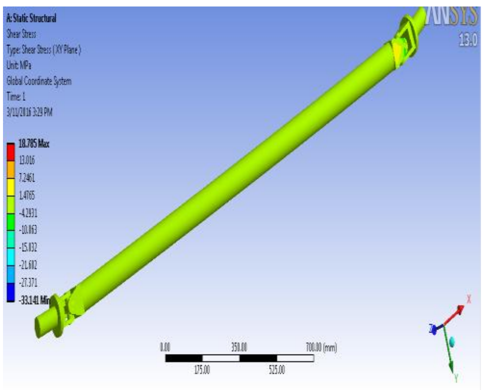

**Figure 4: Shear Stress of Aluminum-Boron/Epoxy drive shaft value is 18.78**

 

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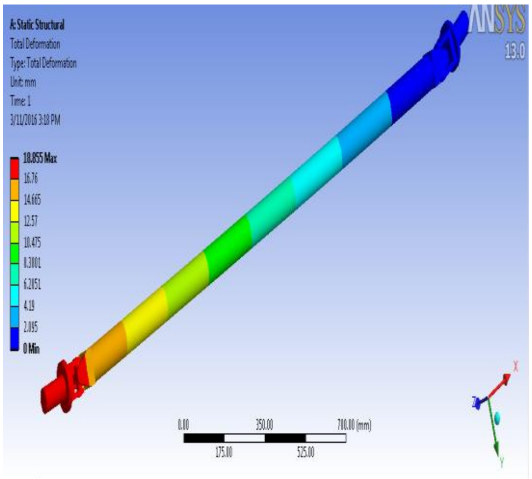


Figure 5: Total Deformation of Aluminum-Boron/Epoxy drive shaft value is 18.85

### 4.2 Carbon/Epoxy Composite Drive Shaft Shear Stress and Total Deformation Values

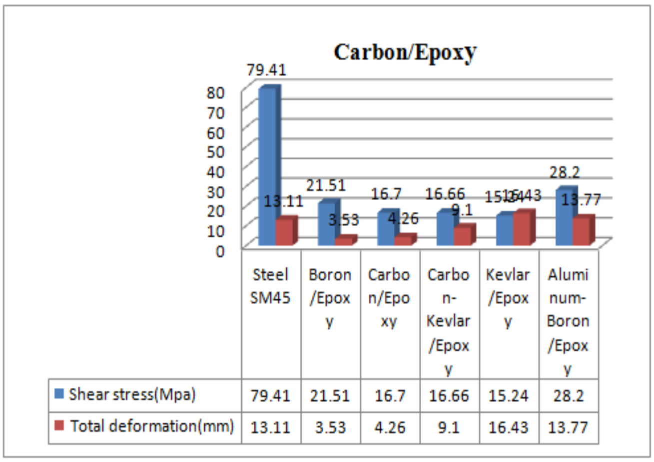


Figure 6: Carbon/Epoxy

### 4.3 Aluminum-Boron/Epoxy Composite Drive Shaft Shear Stress and Total Deformation Values

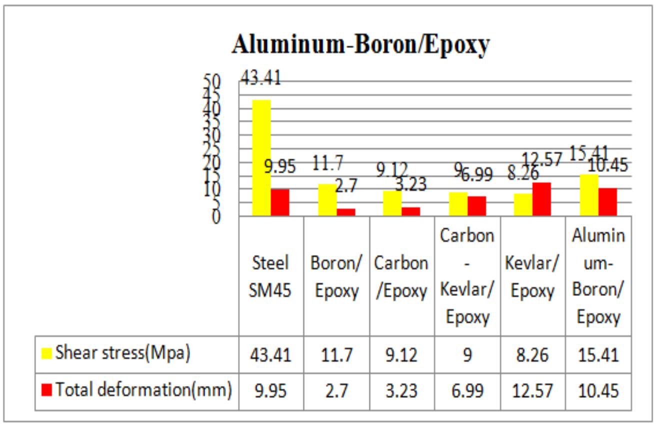


Figure 7: Aluminum-Boron/Epoxy

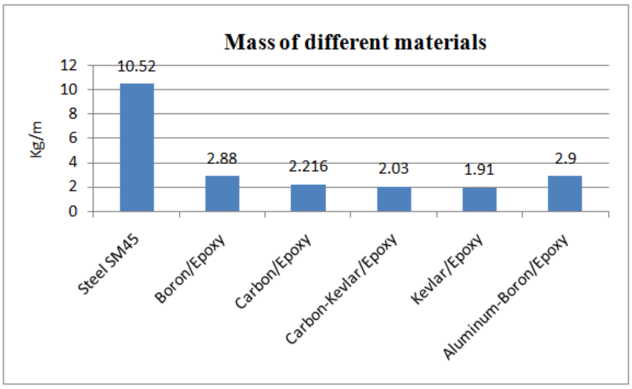


Figure 8: Mass of Different Materials

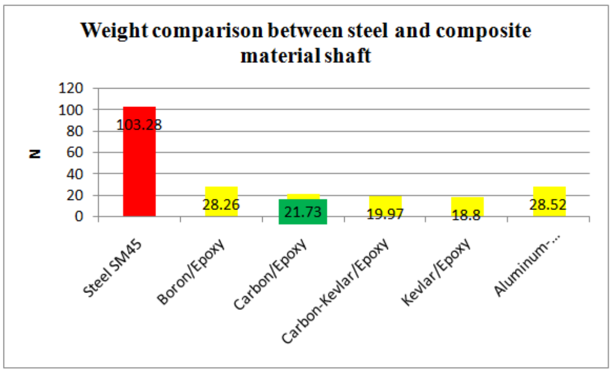


Figure 9: Weight Comparison between Steel and Composite Material Shaft

## V. CONCLUSION

The High Strength Carbon composite drive shafts have been designed to replace the steel drive shaft of an automobile. A one-piece composite drive shaft for rear wheel drive automobile has been designed with High Strength Carbon composites with the objective of minimization of weight of the shaft which was subjected to the constraints such as torque transmission, torsional buckling capacities and natural bending frequency. The High Strength Carbon composite drive shafts have been analyzed to replace the steel drive shaft of an automobile. The usage of composite materials has resulted in considerable amount of weight saving in the range of 62% to 71% when compared to conventional steel drive shaft.

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