

DESIGN AND ANALYSIS OF PROPELLER SHAFT USING VISCO ELASTIC DAMPING MATERIALS

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ABSTRACT:Automotive drive Shaft is a very important components of vehicle. The overall objective of this paper is to design and analyze a composite drive shaft for power transmission. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. In the present buckling analysis is performed to find out buckling factor. Model and harmonic analysis has done to find out natural frequency of shaft and resonance frequency of different materials. Impulse loading condition also taken into analysis to find out damping factor of particular materials.

Index Terms: Automotive drive Shaft, conventional metallic structures, harmonic analysis, damping factor, Impulse loading.

I. INTRODUCTION

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 driver 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. 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.

Description of the Problem

Almost all automobiles (at least those which correspond to design with rear wheel drive and front engine installation) have transmission shafts. The weight reduction of the drive shaft can have a certain role in the general weight reduction of the vehicle and is a highly desirable goal, if it can be achieved without increase in cost and decrease in quality and reliability. It is possible to achieve design of composite drive shaft with less weight to increase the first natural frequency of the shaft and to decrease the bending stresses using various stacking sequences. By doing the same, maximize the torque transmission and torsional buckling capabilities are also maximized.

Classification of Composites

Composite materials can be classified as
Polymer matrix composites
Metal matrix composites
Ceramic Matrix

Technologically, the most important composites are those in which the dispersed phase is in the form of a

fiber. The design of fiber-reinforced composites is based on the high strength and stiffness on a weight basis. Specific strength is the ratio between strength and density. Specific modulus is the ratio between modulus and density. Fiber length has a great influence on the mechanical characteristics of a material. The fibers can be either long or short. Long continuous fibers are easy to orient and process, while short fibers cannot be controlled fully for proper orientation.

All these fibers can be incorporated into a matrix either in continuous lengths or in discontinuous lengths as shown in the Fig 3.1. The matrix material may be a plastic or rubber polymer, metal or ceramic. Laminate is obtained by stacking a number of thin layers of fibers and matrix consolidating them to the desired thickness. Fiber orientation in each layer can be controlled to generate a wide range of physical and mechanical properties for the composite laminate.

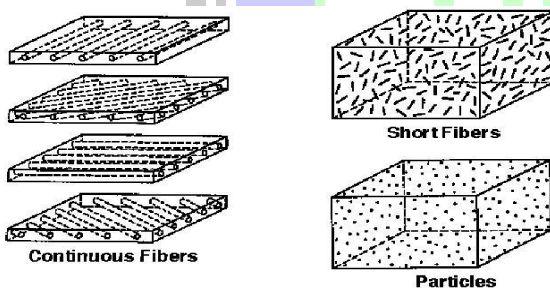


Figure1 Types of fibers

II. Purpose of the Drive Shaft (or Propeller shaft)

The torque that is produced from the engine and transmission must be transferred to the rear wheels to push the vehicle forward and reverse. The drive shaft must provide a smooth, uninterrupted flow of power

to the axles. The drive shaft and differential are used to transfer this torque.

Functions of the Drive Shaft

- 1 First, it must transmit torque from the transmission to the differential gear box.
- 2 During the operation, it is necessary to transmit maximum low-gear torque developed by the engine.
- 3 The drive shafts must also be capable of rotating at the very fast speeds required by the vehicle.
- 4 The drive shaft must also operate through constantly changing angles between the transmission, the differential and the axles. As the rear wheels roll over bumps in the road, the differential and axles move up and down. This movement changes the angle between the transmission and the differential.
- 5 The length of the drive shaft must also be capable of changing while transmitting torque. Length changes are caused by axle movement due to torque reaction, road deflections, braking loads and so on. A slip joint is used to compensate for this motion. The slip joint is usually made of an internal and external spline. It is located on the front end of the drive shaft and is connected to the transmission.

Different Types of Shafts

1. 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 are transmission shafts. Since these shafts carry machine parts such as

pulleys, gears etc., therefore they are subjected to bending moments in addition to twisting.

2 **Machine Shaft:** These shafts form an integral part of the machine itself. For example, the crankshaft is an integral part of I.C.engines slider-crank mechanism.

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

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

4 **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.

III. INTRODUCTION TO PROPULSION

SHAFT:

The torque transmission capability of the propeller shaft for ship should be larger than 3,500 Nm and fundamental natural bending frequency of the propeller shaft should be higher than 6,500 rpm to avoid whirling vibration. The outer diameter of the propeller shaft should not exceed 100 mm due to space limitations. The propeller shaft of transmission system is shown in figure for following specified design requirements as shown in Table. The description of shaft is given in fig . Due to space limitations the outer diameter of the shaft is restricted to 90.24 mm. The one-piece hollow composite drive shaft should satisfy three design specifications, such as static torque transmission capability, torsional buckling capacity and the fundamental natural bending frequency. For given specification, the

damping factor for Steel, carbon Epoxy and E-Glass Epoxy are to be calculated and compared with and without damping material (Rubber).

Sl. No.	Parameter	Notation	Units	Value
1.	Torque	T	N-m	3500
2.	Max Speed	N	RPM	6500
3.	Length	L	m	1.250

Table Problem Specification

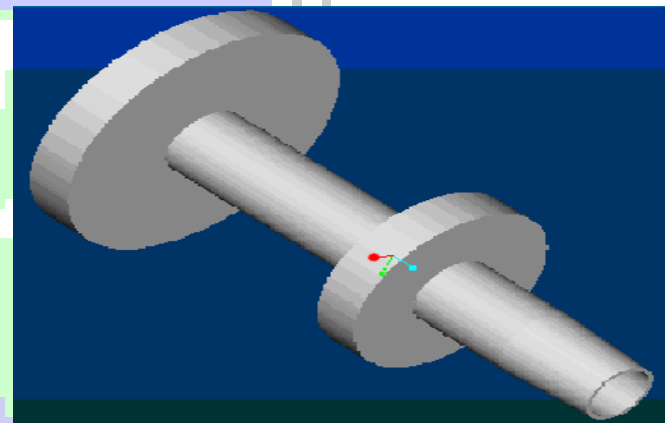


FIG: Pictorial representation of shaft transmission system.

Table Material Properties

Sl. No.	Properties	Units	Steel	Carbon Epoxy	E-Glass Epoxy
1	Young's Modulus E11	N / m ²	2.068e ¹¹	1.34 e ¹¹	50 e ⁹
2	Young's Modulus E22	N / m ²	2.068e ¹¹	7 e ⁹	12 e ⁹
3	Density	kg / m ³	7830	1600	2000
4	Poisson Ratio	-	0.3	0.3	0.3
5	Shear Modulus G	N / m ²	0.8e ¹¹	5.8e ⁹	5.6e ⁹

The material properties listed in Table are used for further calculations and analysis.

STRUCTURAL ANALYSIS OF PROPELLER SHAFT

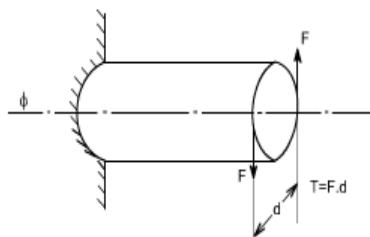
Static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis, however, includes steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

IV. LOADS IN A STATIC ANALYSIS

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (non-zero) displacements
- Temperatures (for thermal strain)
- Fluences (for nuclear swelling)

TORSIONAL AND BUCKLING ANALYSIS



Consider a shaft rigidly clamped at one end and twisted at the other end by a torque $T = F.d$ applied in a plane perpendicular to the axis of the bar such a shaft is said to be in torsion.

Effects of Torsion: The effects of a torsional load applied to a bar are

- (i) To impart an angular displacement of one end cross – section with respect to the other end.
- (ii) To setup shear stresses on any cross section of the bar perpendicular to its axis.

Shaft: The shafts are the machine elements which are used to transmit power in machines.

Twisting Moment: The twisting moment for any section along the bar / shaft is defined to be the algebraic sum of the moments of the applied couples that lie to one side of the section under consideration. The choice of the side in any case is of course arbitrary.

Shearing Strain: If a generator a – b is marked on the surface of the unloaded bar, then after the twisting moment 'T' has been applied this line moves to ab'. The angle 'g' measured in radians, between the final and original positions of the generators is defined as the shearing strain at the surface of the bar or shaft. The same definition will hold at any interior point of the bar.

Modulus of Elasticity in shear: The ratio of the shear stress to the shear strain is called the modulus of elasticity in shear OR Modulus of Rigidity and in

represented by the symbol $G = \frac{\tau}{r}$

Angle of Twist: If a shaft of length L is subjected to a constant twisting moment T along its length, than the angle ϕ through which one end of the bar will

wist relative to the other is known is the angle of twist.

RESULTS DUE TO BUCKLING FACTOR	
MATERIALS	DEFORMATION
STEEL	50.23
CARBON EPOXY	-7.07
GLASS EPOXY	5.0762

Simple Torsion Theory or Development of Torsion Formula : Here we are basically interested to derive an equation between the relevant parameters

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G \cdot \theta}{l}$$

Relationship in Torsion:

Using ANSYS 15.0 the deflection value is calculated. The value is 0.0022 m. The deformed shape of the shaft is shown in the Fig .

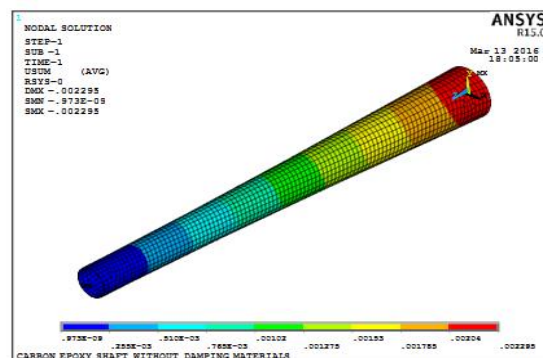


fig: torsional deformation of carbon epoxy shaft.

Using ANSYS 15.0 the deflection value is calculated. The value is 0.0027 m. The deformed shape of the shaft is shown in the Fig .

BUCKLING ANALYSIS

If a beam element is under a compressive load and its length if the orders of magnitude are larger than either of its other dimensions such a beam is called a **columns**. Due to its size its axial displacement is going to be very small compared to its lateral deflection called *buckling*.

Quite often the buckling of column can lead to sudden and dramatic failure. And as a result, special attention must be given to design of column so that they can safely support the loads. In looking at columns under this type of loading we are only going to look at three different types of supports: pin-ended, doubly built-in and cantilever.

1. Steel materials having 50.23 buckling factor when we applied 500 N compression load.
2. carbon epoxy materials having -7.07 buckling factor when we applied 500 N compression load. Here we have negative factor means if we applied pulling load it can buckle.
3. carbon epoxy materials having 5.076 buckling factor when we applied 500 N compression load. Here we have negative factor means if we applied pulling load it can buckle.

MODAL ANALYSIS OF STEEL SHAFT USING SHELL ELEMENT

In this case Steel shaft is modeled using Shell 99. The specifications used are same as in the Static Analysis.

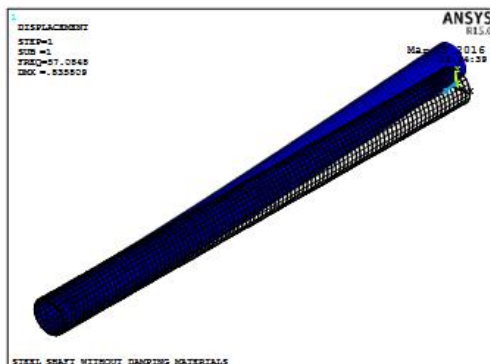


Fig Modal Analysis for Steel Shaft using Shell 281

The fundamental natural frequency of the steel shaft using Shell 281 is shown in the Fig 8.3. The value is 57.08 Hz.

MODAL ANALYSIS OF CARBON EPOXY SHAFT

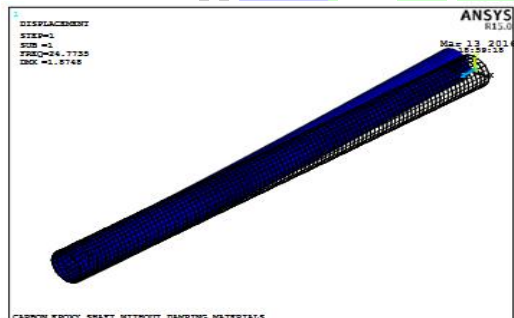


Fig Modal Analysis for Carbon Epoxy Shaft

The fundamental natural frequency of the Carbon Epoxy Shaft is shown in the Fig 8.5. The value is 24.77 Hz.

MODAL ANALYSIS OF E-GLASS EPOXY SHAFT

The fundamental natural frequency of the Carbon Epoxy Shaft with is shown in the Fig 8.7. The value is 33.25 Hz.

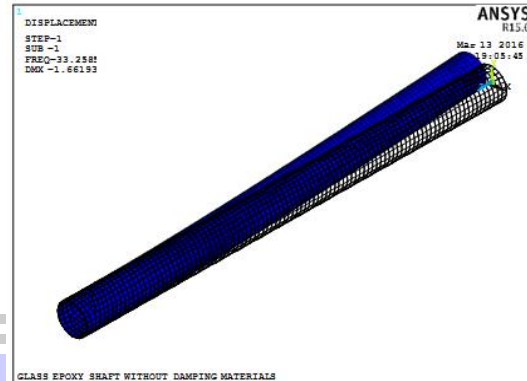


Fig Modal Analysis for E-Glass Epoxy Shaft

V. RESULTS AND DISCUSSIONS

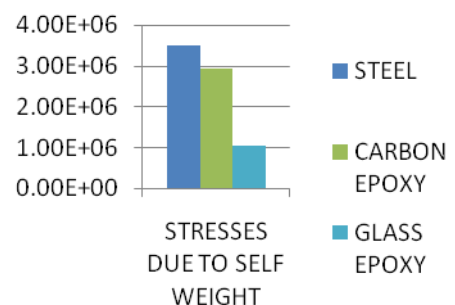
COMPARISON OF DIFFERENT MATERIALS

Table Comparison of Results for Shaft

RESULTS DUE TO SELF WEIGHT		
MATERIALS	DEFORMATION	STRESSES
STEEL	1.17E-04	3.49E+06
CARBON EPOXY	9.49E-05	2.93E+06
GLASS EPOXY	3.07E-04	1.04E+06

From the above results shown in the Table 9.1 it is found that

1. From the above table carbon epoxy having minimum defromation and glass epoxy material are having more defromation.



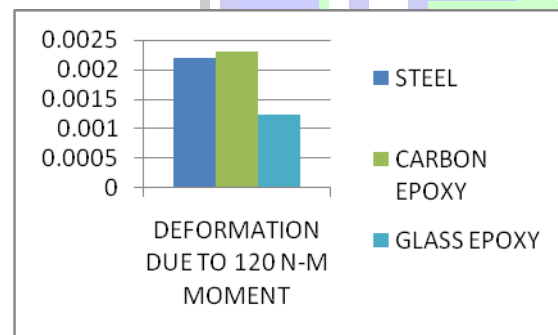
1. From the above table glass epoxy having minimum bending stresses and steel material are having more stresses.

RESULTS DUE TO 120 N-M TORSSION		
MATERIALS	DEFORMATION	STRESSES
STEEL	0.0022	6.40E+07
CARBON EPOXY	0.002295	6.42E+07
GLASS EPOXY	0.00125	6.15E+07

From the above results shown in the Table it is found that

1. From the above table carbon epoxy having minimum deformation and glass epoxy material are having more deformation.

2. carbon epoxy with damping materials are having more bending stresses as compared to remaining materials and glass epoxy materials having minimum stresses.



RESULTS DUE TO BUCKLING FACTOR	
MATERIALS	DEFORMATION
STEEL	50.23
CARBON EPOXY	-7.07
GLASS EPOXY	5.0762

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NATURAL FREQUENCIES				
	STEEL (BEAMELEMENT)	STEEL	CARBON	GLASS
MODE1	56.7	50	24.77	33.2
MODE2	338.2	57.08	47.5	35.34
MODE3	884.02	341	150	201.5
MODE4	1025.86	341.5	269	213
MODE5	1592	639	385	442

VI. CONCLUSIONS

Different analysis has been performed for Steel Shaft, Carbon Epoxy Shaft and E-Glass Epoxy Shaft. The Static, Modal and Transient Dynamic Analyses have been carried out using Finite Element Analysis. Carbon epoxy having minimum deformation and glass epoxy material are having more deformation. Glass epoxy having minimum bending stresses and steel material are having more stresses. An optimal relation between design parameters such as the length, diameter, spacing, and Young's modulus of fibers and the shear modulus of viscoelastic matrix has been derived for achieving maximum damping performance. It has been found that for maximum damping performance, and optimum weight propeller shaft is carbon epoxy material.

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