International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Design and Analysis of Drive Shaft Used In Front Wheel Drive Car

Gosula Suresh[1], K. Bhanuprakash[2], S. Ravi Teja[3], M. Chintu[4], K. Saikumar

[1] Assistant Professor, ACE Engineering College, Ghatkesar, Hyderabad, India
[2, 3, 4, 5] Students, ACE Engineering College, Ghatkesar,Hyderabad, India

ABSTRACT:

Drive shaft has a major role in vehicle transmission system. It is a mechanical part which is used to transfer power from engine to wheel. Almost all automobiles have transmission shafts. Drive shafts, as power transmission tubing are used in many applications including cooling towers, pump sets, aerospace, trucks and automobiles. In Front wheel drive (FWD) car, maximum power is transmitted through drive shaft. This power transmission mainly depends on size of drive shaft.The drive shaft is subjected to torsional stresses and bending stresses. To achieve more reliability, less cost and high quality, the drive shaft should be with less weight and more strength and stiffness.Because of this reason weight optimization of front wheel drive shaft plays a major role in achievingthese major goals like less cost, high quality and reliability. The aim of this paper is to design of front wheel drive shaft for maximum power transmitted from FWD car. This project includes detailed finite element analysis of front wheel drive shaft for torsional and bending loads. The project involves performing analysis for drive shaft with conventional steel material and also with different composite materials like carbon/Epoxy and E-glass/Epoxy. In this project, the design of front wheel drive is done for both steel and composite material for torsional and bending loads.A static, modal and buckling analysis is done for different composite materials with different layer orientation to calculate weight, deflections, stresses and vibration characteristics of the front wheel drive. The results obtained from the analysis are compared and the best material is proposed based on the weight to strength ratio. Design of front wheel drive shaft is done in NX CAD software and Ansys11.0 software is used for static analysis of front wheel drive shaft.

Introduction

A driveshaft or driving shaft is a device that transfers power from the engine to the point where work is applied. In the case of automobiles, the drive shaft transfers engine torque to the drive axle, which connects the two wheels together on opposite sides and with which they turn. The driveshaft is also sometimes called propeller shaft. Drive shafts are essentially carriers of torque. Before they became a vogue, older automobiles used chain drive and even generators to transmit power to the wheels. Drive shaft today, however, have U-joints, devices which help them to move and down during suspension. Some driveshafts also have another kind of joint, called slip joints, which allow them to adjust their lengths to the movement of the suspension.Adjustments aside, drive shafts are of different lengths depending on their use. Long shafts are used in front-engine, rear-drive vehicles while shorter ones are used when power must be sent from a central differential, transmission, or transaxle. Because of the load they Carrie, driveshaft must be strong enough to bear the stress that is required in the transmission of power.

Drive Shaft Arrangement in a Car Model

Conventional two-piece drive shaft arrangement for rear wheel vehicle driving system is shown in fig.1.

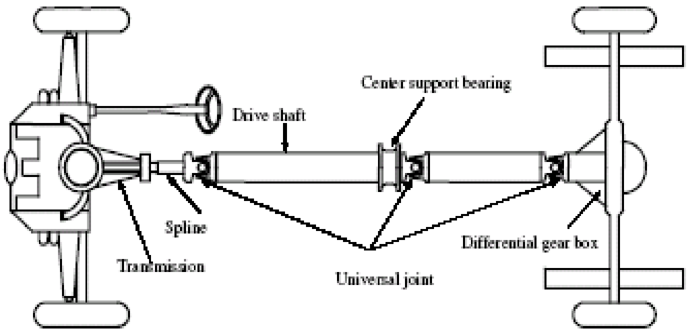


Fig 1: Conventional two-piece drive shaft arrangement for rear wheel vehicle driving system

Parts of Drive Shaft and Universal Joint

Parts of drive shaft and universal joint are shown in fig.2.Parts of drive shaft and universal joints are

1. U-bolt nut 2. U-bolt washers 3. U-bolt
4. Universal joint journal 5. Lubrication fitting 6. Snap ring.
7. Universal joint sleeve yoke 8. Spline seal 9. Dust cap
10. Drive shaft tube

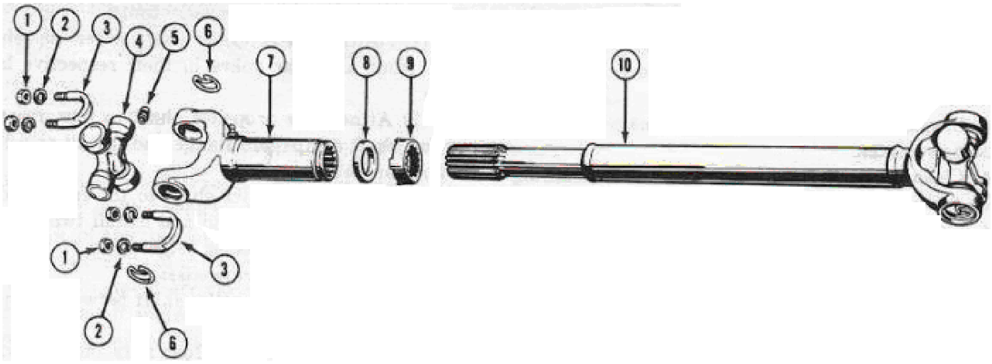


Fig 2: Parts of drive shaft and universal joint.

Merits of Composite Drive Shaft

1. They have high specific modulus and strength.
2. Reduced weight
3. The fundamental natural frequency of the carbon fiber composite drive shaft can be twice as high as that of steel or aluminum because the carbon fiber composite material has more than 4 times the specific stiffness of steel or aluminum, which makes it possible to manufacture the drive shaft of passenger cars in one piece. A one-piece composite shaft can be manufactured so as to satisfy the vibration requirements. This eliminates all the assembly, connecting the two piece steel shafts and thus minimizes the overall weight, vibrations and the total cost [4].
4. Due to the weight reduction, fuel consumption will be reduced [3].
5. They have high damping capacity hence they produce less vibration and noise [4].
6. They have good corrosion resistance [3].
7. Greater torque capacity than steel or aluminum shaft [5].
8. Longer fatigue life than steel or aluminum shaft [5].
9. Lower rotating weight transmits more of available power [5].

Demerits of Conventional Drive Shaft

1. They have less specific modulus and strength [3].
2. Increased weight [3].
3. Conventional 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. Therefore the steel drive shaft is made in two sections connected by a support structure, bearings and U-joints and hence over all weight of assembly will be more [4].
4. Its corrosion resistance is less as compared with composite materials [4].
5. Steel drive shafts have less damping capacity

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. .

Objectives of the Work

This work deals with the replacement of a conventional steel drive shaft with E-Glass/ Epoxy, High Strength Carbon/Epoxy and High Modulus Carbon/Epoxy composite drive shafts for an automobile application.

Analysis

1. Modeling of the High Strength Carbon/Epoxy composite drive shaft using ANSYS
2. Static, Modal and Buckling analysis are to be carried out on the finite element model of the High Strength Carbon/Epoxy composite drive shaft using ANSYS
3. To investigate
   a) The stress and strain distributions in E-Glass/ Epoxy, High Strength Carbon/Epoxy and High Modulus Carbon/Epoxy composite drive shafts.
   b) The effect of centrifugal forces on the torque transmission capacity of the composite drive shafts.

c) The effect of transverse shear and rotary inertia on the fundamental lateral natural frequency of the shaft.

Literature Survey:

Bhirud Pankaj Prakash, Bimlesh Kumar Sinha: Has Published A Journal On "Analysis Of Drive Shaft". This paper includes 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.

V. S. Bhajantri , S. C. Bajantri , A. M. Shindolkar , S. S. Amarapure: Have Written A Paper On "Design And Analysis Of Composite Drive Shaft". This paper presents that Substituting composite structures for conventional metallic structures has much advantage because of higher specific stiffness and strength of composite materials. Composite materials have been widely used to improve the performance of various types of structures. Compared to conventional materials, the main advantages of composites are their superior stiffness to mass ratio as well as high strength to weight ratio.

Sagar R Dharmadhikari, 1 Sachin G Mahakalkar, 2 Jayant P Giri, 3 Nilesh D Khutafale: submitted a paper on ""Design and Analysis of Composite Drive Shaft using ANSYS and Genetic Algorithm". This paper presents Drive shaft is the main component of drive system of an automobile. Use of conventional steel for manufacturing of drive shaft has many disadvantages such as low specific stiffness and strength. Conventional drive shaft is made up into two parts to increase its fundamental natural bending frequency. Two piece drive shaft increases the weight of drive shaft which is not desirable in today's market. Many methods are available at present for the design optimization of structural systems and these methods based on mathematical programming techniques involving gradient search and direct search. These methods assume that the design variables are continuous. But in practical structural engineering optimization, almost all the design variables are discrete. This is due to the availability of components in standard sizes and constraints due to construction and manufacturing practices.

Kiran A. Jagtap, Prof. P. M. Sonawane: has published a paper on "Design and Analysis of Drive Shaft for Heavy Duty Truck". In automobiles the drive shaft is used for the transmission of motion from the engine to the differential. An automotive propeller shaft, or drive shaft, transmits power from the engine to differential gears of rear wheel-driving vehicle. The power from Transmission shaft should be transmitted to the Rear axle of the vehicle. The axis of the Transmission and the connecting member of Rear axle are at an angle, which changes with the variation in load or the road condition. To facilitate the power transmission at a variable angle a Propeller shaft is used. With respect to the geometrical construction the Propeller shafts are categorized into single piece two-piece and three-piece propeller shafts. In case of two or multi stage propeller shaft length of the rear propeller shaft is subjected to variation while the remaining propeller shafts are rigid members i.e. do not change in length. The variation in the length of rear propeller shaft is allowed using a splined shaft. Generally length of the propeller shaft is decided after freezing the remaining aggregates.

This work deals with the replacement of a conventional steel drive shaft with E-Glass/ Epoxy, High Strength Carbon/Epoxy and High Modulus Carbon/Epoxy composite drive shafts for an automobile application.

Analysis

4. Modeling of the High Strength Carbon/Epoxy composite drive shaft using ANSYS
5. Static, Modal and Buckling analysis are to be carried out on the finite element model of the High Strength Carbon/Epoxy composite drive shaft using ANSYS
6. To investigate
   d) The stress and strain distributions in E-Glass/ Epoxy, High Strength Carbon/Epoxy and High Modulus Carbon/Epoxy composite drive shafts.
   e) The effect of centrifugal forces on the torque transmission capacity of the composite drive shafts.

f) The effect of transverse shear and rotary inertia on the fundamental lateral natural frequency of the shaft.

Design of Steel Drive Shaft

Specification of the Problem

The torque transmission capability of the drive shaft for passenger cars, small trucks, and vans 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 drive shaft outer diameter should not exceed 100 mm due to space limitations. Here outer diameter of the shaft is taken as 100 mm. The drive shaft of transmission system is to be designed optimally for following specified design requirements as shown in Table

Table 1: Design requirements and specifications

Sr.No.	Name	Notation	Unit	Value
1.	Ultimate Torque	T_{max}	Nm	3500
2.	Max. Speed of shaft	N_{max}	rpm	6500
3.	Length of shaft	L	mm	1850

Steel (SM45C) used for automotive drive shaft applications. The material properties of the steel (SM45C) are given in Table 3.2 [5]. The steel drive shaft should satisfy three design specifications such as torque transmission capability, buckling torque capability and bending natural frequency.

Table 2:Mechanical properties of Steel (SM45C)

Mechanical properties	Symbol	Units	Steel
Young's Modulus	E	GPa	207.0
Shear modulus	G	GPa	80.0
Poisson's ratio	ν	-----	0.3
Density	ρ	Kg/m^3	7600
Yield Strength	S_y	MPa	370
Shear Strength	S_s	MPa	--

Torque Transmission Capacity of the Drive Shaft

$$T = S_s \frac{\pi\left(d_o^4 - d_i^4\right)}{16T\,d_o} \qquad \text{----- (3.1)}$$

3.3 Torsional Buckling Capacityofthe Drive Shaft

If $\frac{1}{\sqrt{1-\nu^2}} \frac{L^2 t}{(2r)^3} > 5.5$, it is called as Long shaft otherwise it is called as Short & Medium shaft.

For long shaft, the critical stress is given by

$$\tau_{cr} = \frac{E}{3\sqrt{2}(1-\nu^2)^{3/4}} (t/r)^{3/2} \qquad \text{----- (3.2)}$$

For short & medium shaft, the critical stress is given by

$$\tau_{cr} = \frac{4.39E}{(1-\nu^2)} (t/r)^2 \sqrt{1 + 0.0257(1-\nu^2)^{3/4} \frac{L^3}{(rt)^{1.5}}} \qquad \text{----- (3.3)}$$

The relation between the torsional buckling capacity and critical stress is given by

$$T_{cr} = \tau_{cr} 2\pi r^2 t \qquad \text{----- (3.4)}$$

Lateral or Bending Vibration

The shaft is considered as simply supported beam undergoing transverse vibration or can be idealized as a pinned-pinned beam. Natural frequency can be found using the following two theories.

Bernoulli-Euler Beam Theory-N_{crbe}

It neglects the both transverse shear deformation as well as rotary inertia effects. Natural frequency based on the Bernoulli-Euler beam theory is given by,

$$f_{nbe} = \frac{\pi p^2}{2L^2} \sqrt{\frac{EI_x}{m_1}} \qquad \text{------ (3.5)}$$

Where p = 1, 2... ……

$$N_{crbe} = 60 f_{nbe} \qquad \text{------ (3.6)}$$

Timoshenko Beam Theory-N_{crt}

It considers both transverse shear deformation as well as rotary inertia effects. Natural frequency based on the Timoshenko beam theory is given by,

$$f_{nt} = K_s \frac{30\pi p^2}{L^2}\sqrt{\frac{Er^2}{2\rho}} \quad \text{------ (3.7)}$$

$$N_{crt} = 60 f_{nt} \quad \text{------ (3.8)}$$

$$\frac{1}{K^2_s} = 1 + \frac{n^2\pi^2 r^2}{2L^2}\left[1 + \frac{f_s E}{G}\right] \quad \text{------ (3.9)}$$

f_s= 2 for hollow circular cross-sections

The relation between Timoshenko and Bernoulli-Euler Beam Theories

The relation between Timoshenko and Bernoulli-Euler beam theories is given by,

$$f_{nt} = K_s f_{nbe} \quad \text{------ (3.10)}$$

Specification of the Problem

The specifications of the composite drive shaft of an automotive transmission are same as that of the steel drive shaft for optimal design.

Assumptions

1. The shaft rotates at a constant speed about its longitudinal axis.
2. The shaft has a uniform, circular cross section.
3. The shaft is perfectly balanced, i.e., at every cross section, the mass center coincides with the geometric center.
4. All damping and nonlinear effects are excluded.
5. The stress-strain relationship for composite material is linear & elastic; hence, Hooke's law is applicable for composite materials.
6. Acoustical fluid interactions are neglected, i.e., the shaft is assumed to be acting in a vacuum.
7. Since lamina is thin and no out-of-plane loads are applied, it is considered as under the plane stress.

Selection of Reinforcement Fiber

Fibers are available with widely differing properties. Review of the design and performance requirements usually dictate the fiber/fibers to be used.

- **Carbon/Graphitefibers:** its advantages include high specific strength and modulus, low coefficient of thermal expansion, and high fatigue strength. Graphite, when used alone has low impact resistance. Its drawbacks include high cost, low impact resistance, and high electrical conductivity.
- **Glass fibers**: Its advantages include its low cost, high strength, high chemical resistance, and good insulating properties. The disadvantages are low elastic modulus, poor adhesion to polymers, low fatigue strength, and high density, which increase shaft size and weight. Also crack detection becomes difficult.
- **Kevlar fibers:** Its advantages are low density, high tensile strength, low cost, and higher impact resistance. The disadvantages are very low compressive strength, marginal shear strength, and high water absorption. Kevlar is not recommended for use in torque carrying application because of its low strength in compression and shear.

Here, both glass and carbon fibers are selected as potential materials for the design of shaft.

Selection of Materials

Based on the advantages discussed earlier, the E-Glass/Epoxy, High Strength Carbon/Epoxy and High Modulus Carbon/Epoxy materials are selected for composite drive shaft. The Table 4.1shows the properties of the E-Glass/Epoxy, High Strength Carbon/Epoxy and High Modulus Carbon/Epoxy materials used for composite drive shafts [3].

Table 3: Properties of E-Glass/Epoxy, HS Carbon/Epoxy and HM Carbon/Epoxy

Sl.No	Property	Units	E-Glass/Epoxy	HS Carbon/Epoxy	HM Carbon/Epoxy
1.	E_{11}	GPa	50.0	134.0	190.0
2.	E_{22}	GPa	12.0	7.0	7.7
3.	G_{12}	GPa	5.6	5.8	4.2
4.	ν_{12}	-	0.3	0.3	0.3
5.	$S^t_1= S^c_1$	MPa	800.0	880.0	870.0
6.	$S^t_2= S^C_2$	MPa	40.0	60.0	54.0
7.	S_{12}	MPa	72.0	97.0	30.0
8.	ρ	Kg/m^3	2000.0	1600.0	1600.0

FINITE ELEMENT ANALYSIS

In this project finite element analysis was carried out using the FEA software ANSYS 11.0. The primary unknowns in this structural analysis are displacements and other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

Boundary Conditions

The finite element model of HS Carbon/Epoxy shaft is shown in Fig. One end is fixed and torque is applied at other end,

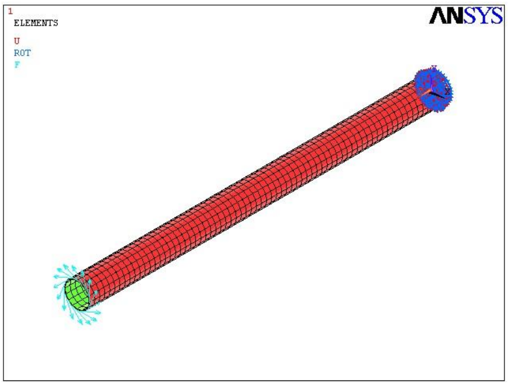


Fig Finite element model of HS Carbon/Epoxy shaft

MODAL ANALYSIS

When an elastic system free from external forces is disturbed from its equilibrium position it vibrates under the influence of inherent forces and is said to be in the state of free vibration. It will vibrate at its natural frequency and its amplitude will gradually become smaller with time due to energy being dissipated by motion. The main parameters of interest in free vibration are natural frequency and the amplitude. The natural frequencies and the mode shapes are important parameters in the design of a structure for dynamic loading conditions.

Modal analysis is used to determine the vibration characteristics such as natural frequencies and mode shapes of a structure or a machine component while it is being designed. It can also be a starting point for another more detailed analysis such as a transient dynamic analysis, a harmonic response analysis or a spectrum analysis. Modal analysis is used to determine the natural frequencies and mode shapes of a structure or a machine component.

The rotational speed is limited by lateral stability considerations. Most designs are sub critical, i.e. rotational speed must be lower than the first natural bending frequency of the shaft. The natural frequency depends on the diameter of the shaft, thickness of the hollow shaft, specific stiffness and the length. Boundary conditions for the modal analysis are shown in Fig

Buckling Analysis:

Buckling analysis is a technique used to determine buckling loads(critical loads) at which a structure becomes unstable, and buckled mode shapes(The characteristic shape associated with a structure's buckled response).

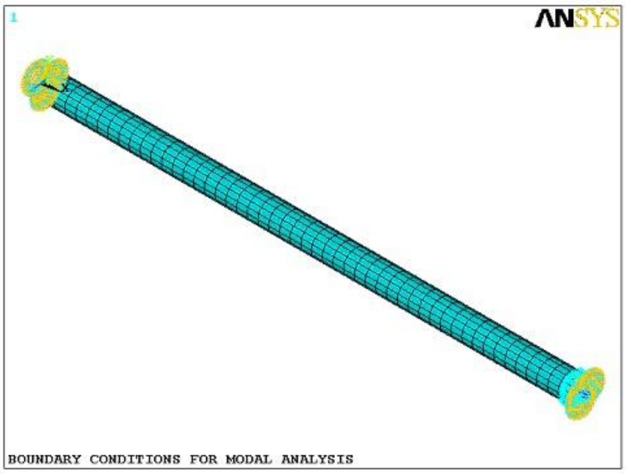


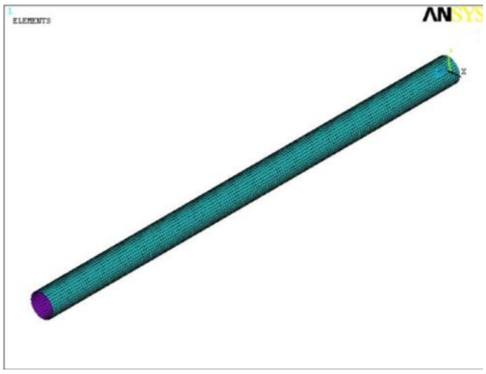
Figure Boundary Conditions for the Modal Analysis

For thin walled shafts, the failure mode under an applied torque is torsional buckling rather than material failure. For a realistic driveshaft system, improved lateral stability characteristics must be achieved together with improved torque carrying capabilities. The dominant failure mode, torsional buckling, is strongly dependent on fiber orientation angles and ply stacking sequence.

Results & Discussions

STEEL:

Finite element model:

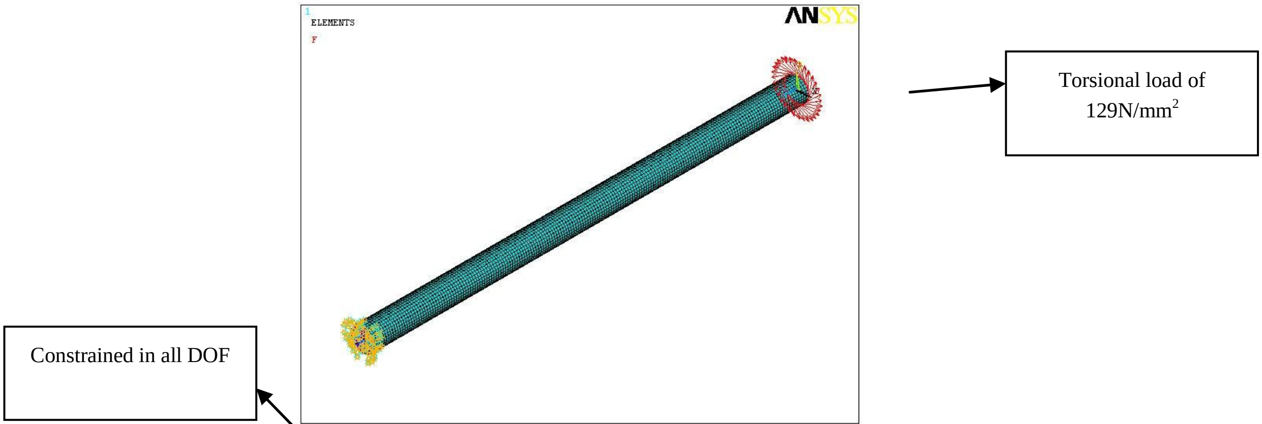


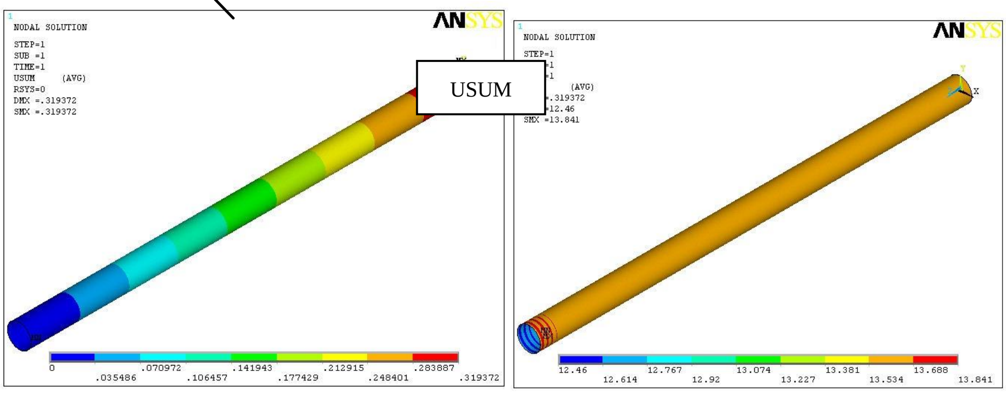
Element type: shell63

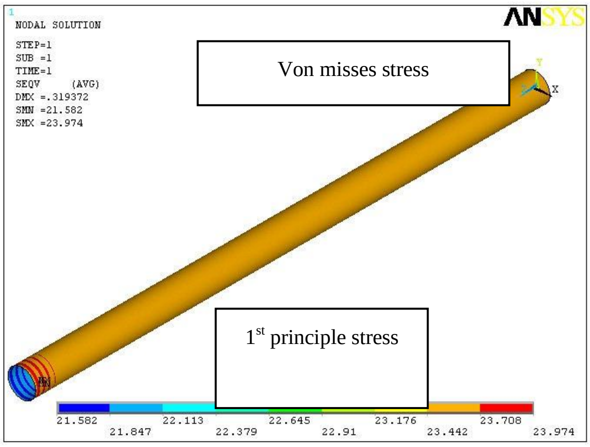
Total no. of elements: 5920

Static analysis:

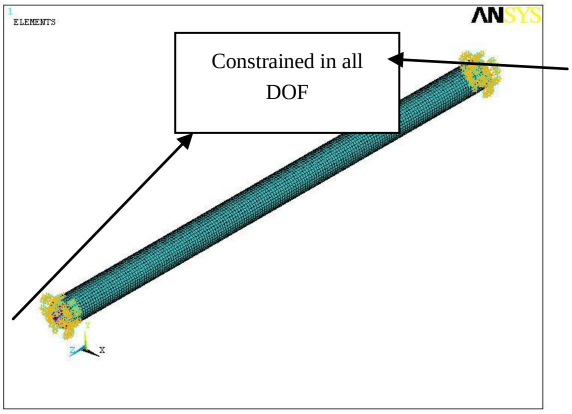
Loading conditions:

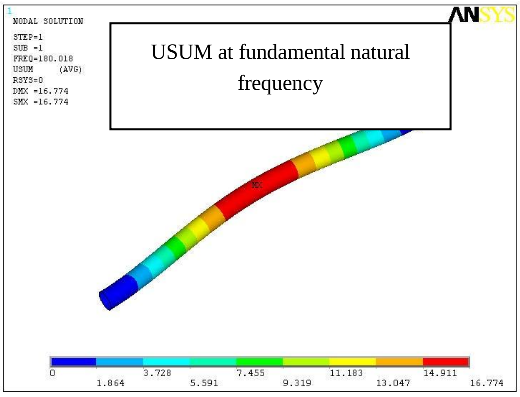




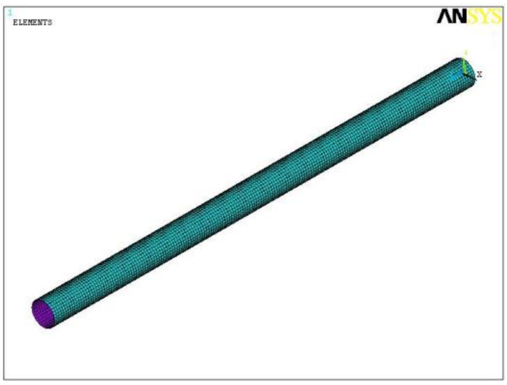


Modal analysis:

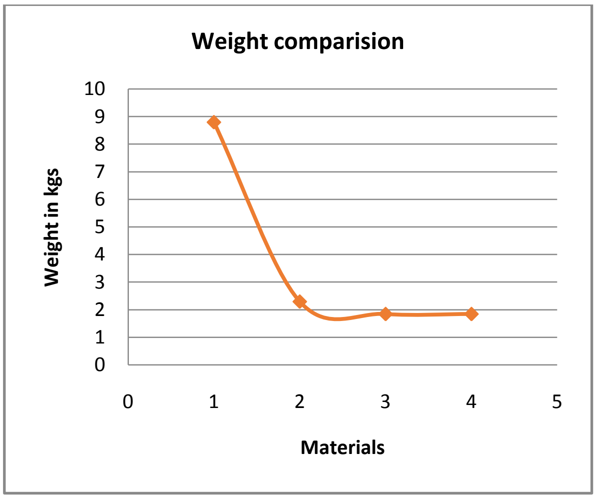


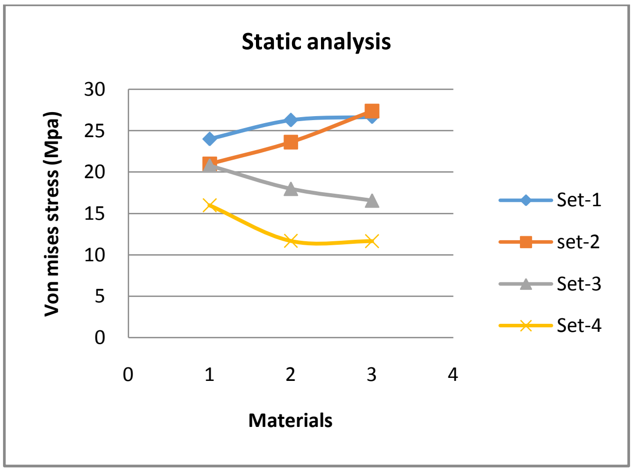


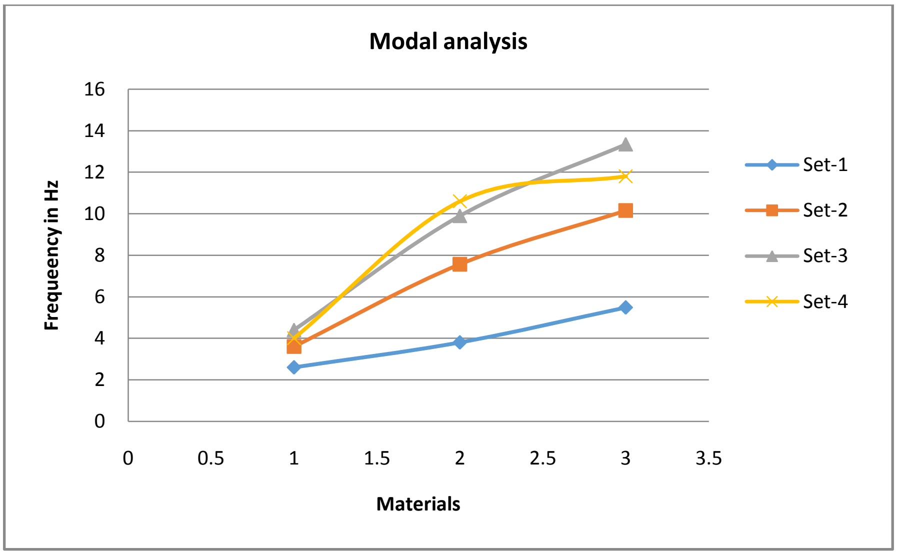
EGLASS/EPOXY:
Finite element model:

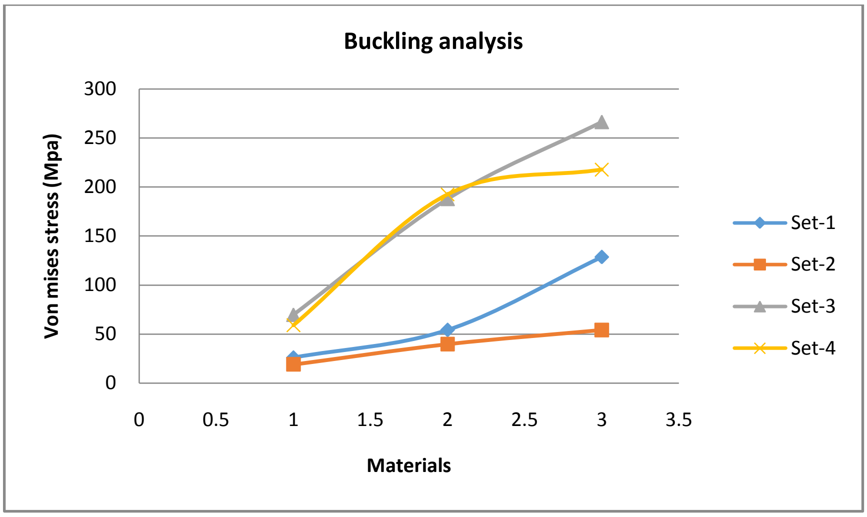


Insert Table
Graphs:









In steel, total deflection is very less comparing with other materials. Von misses stress is also within the yield strength. But the frequency occurred in the buckling is very high. And also the weight of the steel driveshaft is very high (8.8kgs), comparing with the rest of the materials.

Stresses developed in the Eglass/epoxy are within the allowable stresses, in all sets. Weight of the driveshaft made up of Eglass/epoxy is low, comparing with steel, but high comparing with other two materials. In the first set, frequency in the buckling is very low.

Weight of the Hscarbon/epoxy driveshaft is very less, comparing with the other materials. Total deflection and frequency are less in the set-1.

Stresses developed in the Hmcarbon/epoxy are within the yield strength. Weight of the Hmcarbon/epoxy driveshaft is same as the weight of the Hscarbon/epoxy driveshaft, and lower than the other two materials. Von misses stresses in the buckling are high.

Conclusion:

From the above table, by comparing the driveshaft with different materials and plies orientations, we can conclude that, Eglass/epoxy of set-1 can withstand all the applied loads. Even though weight of the Eglass/epoxy driveshaft is little bit higher, it is suggestable material for the driveshaft, and the layer orientation is ±45º.

References

1. “Analysis of Drive Shaft” By Bhirud Pankaj Prakash, Bimlesh Kumar Sinha.
2. “Design And Analysis Of Composite Drive Shaft” By V. S. Bhajantri , S. C. Bajantri , A. M. Shindolkar , S. S. Amarapure:
3. Design And Analysis Of Composite Drive Shaft Using Ansys And Genetic Algorithm By Sagar R Dharmadhikari, Sachin G Mahakalkar, Jayant P Giri, Nilesh D Khutafale: “Design and Analysis of Drive Shaft for Heavy Duty Truck” By Kiran A. Jagtap, Prof. P. M. Sonawane.
4. Suresh Gosula, “Study on Impact of Microstructure and Hardness of Aluminum Alloy After Friction Stir Welding”, International Journal Of Advanced Engineering Research and Science (IJAERS), Volume-4, Issue-9, (Sep-2017) ISSN: 2349-6495.
5. Suresh Gosula, Ragamshetty Mounika (Ph.D) in KU. “Enhanced Mechanical and Micro Structural Properties of AL-Mg-Si Age Hardening Alloy To Heat Treatment Alloy Via Friction stir welding” International Journal Of
6. Advanced Engineering Research And Development(Ijaerd),Volume-4,Issue-10,(Oct-2017) Issn:2348-4470
7. Suresh Gosula,C.Venkatesh,B.Chaitanya,K.Sai Mahesh Yadav(NITW) “Effect of Deformation on the properties of Al-4Cu-05Mg-2SiC Powder Metallurgy Composite” International Journal Of Civil, Mechanical and Science (IJCMES),Volume-3,ISSUE-6,(Dec-2017)
8. Suresh Gosula, C.Venkatesh, CH.Raju, M.Mahender “The Effect of Friction Stir Welding on Aluminum Alloy To Alloy steel” International Journal OfCreative Research(IJCRT),Volume-5,ISSUE-4,(Dec-2017)
9. Suresh Gosula, Fabrication of Go-Kart (Guided the Graduate Students) International Journal of Scientific & Engineering Research (IJSER) Volume-9, ISSUE-4, ISSN2229-5518, (April-2018)