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Design and Static Analysis of Forward Drive Shaft Using Composite Materials

K Faiz Hibathulla
CAD/CAM
Department of Mechanical Engineering
Tadipatri Engineering College

Sri S.V.Ramana, M.Tech
Assistant Professor
Department of Mechanical Engineering
Tadipatri Engineering College

C.Raghunatha Reddy H.O.D
Assistant Professor
Department of Mechanical Engineering
Tadipatri Engineering College

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 shaftThis 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 achieving these major goals like less cost, high quality and reliability. This project deals with the 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, E-glass/Epoxy and Kevlar/Epoxy. A number of papers were published previously on the similar lines, but most of them were restricted only for static and modal analysis only. This project is extended in performing harmonic and shock analysis also. In this project, the design of front wheel drive is done by theoretical formulas for both steel and composite material for torsional and bending loads. A static, modal, harmonic and shock 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.

I. Introduction
Drive Shaft:
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.

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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 drive shafts also have another kind of joint, called slip joints, which allow them to adjust their lengths to the movement of the suspension.

CONSTANT VELOCITY (CV) JOINT:

CV joint accommodates angular changes more effectively between ends of one-piece drive shaft. For front wheel drive systems, the short distance between wheel hubs and final drive housing. Combined with a large movement of wheel due to suspension deflection and steering angle i.e, maximum drive angle of universal joints are great. A CV joint at each end of drive shaft meets the angle requirement.

1.1Fig. One-piece drive shaft

COMPOSITE MATERIALS:

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive.

II. LITERATURE SUVEY

Anupam Singhal, R. K. Mandloi: [1]have published a entitled on "Failure Analysis of Automotive FWD Flexible Drive Shaft ". According to this, Drive shafts are carriers of torque. They are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia.

D.DINESH, F.ANAND RAJU: have written a title on "Optimum [2]Design And Analysis Of A Composite Drive Shaft For An Automobile By Using Genetic Algorithm And Ansys". In this title Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This work deals with the replacement of conventional two-piece steel drive shafts with a single-piece e-glass/epoxy, high strength carbon/epoxy and high modulus carbon/epoxy composite drive shaft for an automotive application.

BHIRUD PANKAJ PRAKASH, BIMLESH KUMAR SINHA: has published a journal on "ANALYSIS OF DRIVE SHAFT". This

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paper includes Composite [3]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 [4]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 [5]on part of the drive train extending life[6].

TORQUE TRANSMISSION CAPACITY OF ONE-PIECE DRIVE SHAFT

CALCULATION OF TORQUE TRANSMISSION CAPACITY OF ONE-PIECE DRIVE SHAFT:

Input:

Outer diameter of shaft(Do)= 30 mm

Inner diameter of shaft (Di)= 20 mm

Length of shaft (L) = 500 mm

Output:

Material properties of steel:

S.no	Mechanical Properties	Symbol	Unit	Value
1	Young's modulus	E	GPa	207
2	Shear modulus	G	GPa	80
3	Poisson's ratio	υ		0.3
4	Density	ρ	Kg/m3	7850
5	Yield strength	Sy	MPa	300
6	Shear strength	Ss	MPa	250

Torque transmission capacity of drive shaft:

$$T = Ss \frac{\pi * \left((Do)^4 - (Di)^4 \right)}{16 * Do}$$

=1063.020 N.m

Load acting on drive shaft (F) =

$$\frac{\text{Torque}}{\text{Perpendicular distance from fixed constraints}}$$

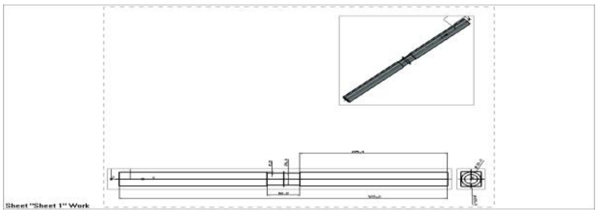
= 2126.04N

Torque transmission capacity value applied for all different materials used in Drive shaft and from the analysis results, suitable material will be proposed to one-piece drive shaft.

III. MODELING OF ONE-PIECE DRIVE SHAFT

2D SKETCH OF ONE-PIECE DRIVE SHAFT:

2d sketch and 3D model of one-piece drive shaft done in unigraphics software based on input.



3.1Fig: 2D sketch of shaft

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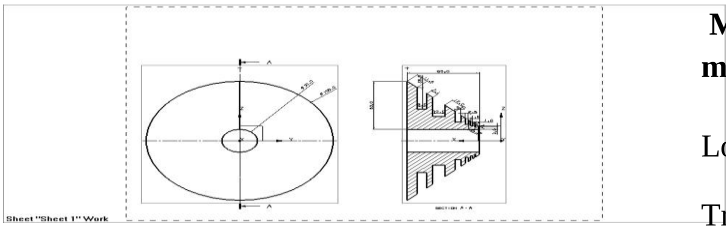


3.2Fig: 2D sketch of V-joint

IV. STATIC ANALYSIS OF ONE-PIECE DRIVE SHAFT:

A static analysis can however include steady inertia loads and time varying loads that can be approximated as static equivalent loads. The 3d model of the Drive shaft is created in NX-CAD and converted into paranoid. The paranoid file is imported into ANSYS and finite element analysis is carried out using ANSYS software.

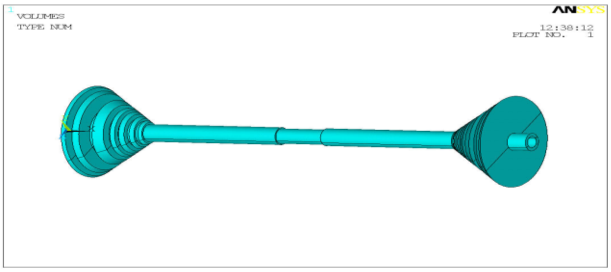
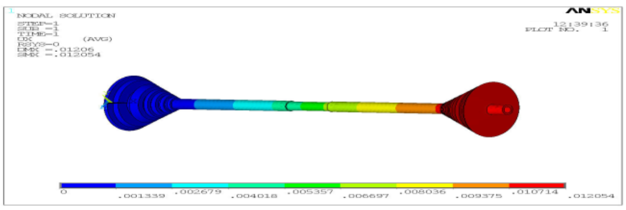


Fig: Geometric model of the drive shaft

RESULTS:

DEFLECTIONS:



4.1 Fig: Results in displacement of drive shaft in X-Direction

STATIC ANALYSIS OF COMPOSITE MATERIALS USED FOR ONE-PIECE DRIVE SHAFT:

Material used for drive shaft is composite materials (E-Glass/Epoxy):

Longitudinal Modulus (E_x): **50 GPa**

Transverse Modulus (E_Y): **12 GPa**

Shear modulus (G_{ay}): **5 .6GPa**

Shear modulus (G_{ym}): **5.6 GPa**

Shear modulus (G_{xz}): **5.6 GPa**

Poisson’s Ratio: **0.33**

Density: **2000 Kg/m3**

Ply orientation: **-45^o, 0^o, 0^o, 45^o**

Ply-angle/ ply orientation:

Angle-ply or axially biased composite laminates are an important class of laminates because they combine good properties in the axial and shear directions. The Ply- angle architecture, which offered one of the best combinations of axial and shear properties, had a much lower experimental compressive strength than that predicted using the maximum stress or maximum strain failure criteria.

Element Types used:

Name of the Element: SOLID 185

Number of Nodes: 20

DOF: UX, UY & UZ

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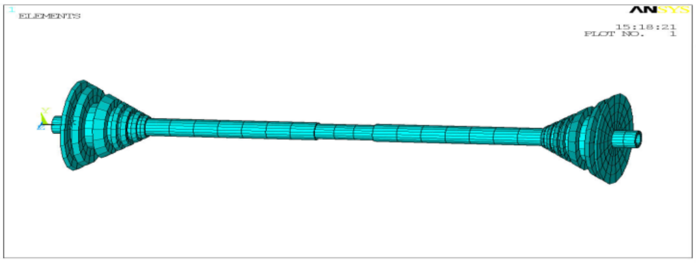
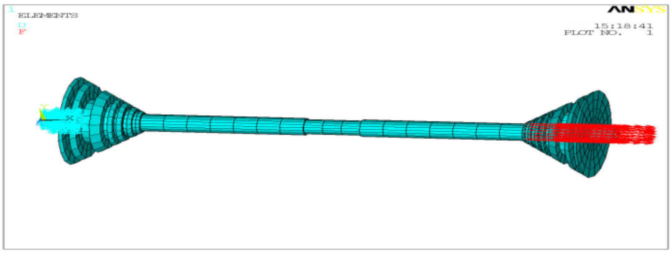


4.2 Fig: Meshed model of one-piece drive shaft

BOUNDARY CONDITIONS:

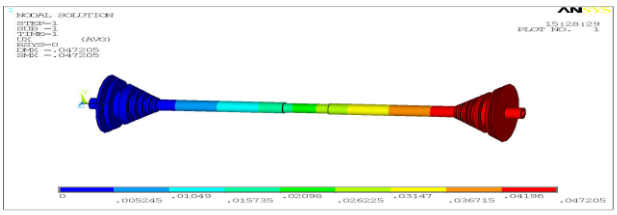
Boundary conditions for one-piece drive shaft are given as one end fixed (constrained) with zero displacement in linear and rotation moment. Estimated torque (1063.02 N.m) passed through another end for all different types of material.



4.3 Fig: Applied boundary conditions of drive shaft.

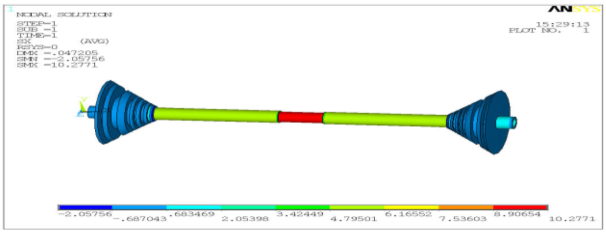
RESULTS:

DEFLECTIONS:



4.4 Fig: Results in displacement of one-piece drive shaft in X-Direction

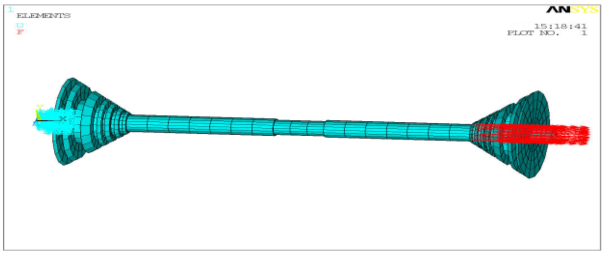
STRESSES:



4.5 Fig: Stresses formed on one piece drive shaft in X-Direction

BOUNDARY CONDITIONS:

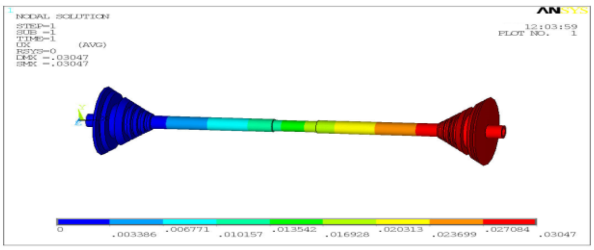
Boundary conditions for one-piece drive shaft are given as one end fixed (constrained) with zero displacement in linear and rotation moment. Estimated torque (1063.02 N.m) passed through another end for all different types of material.



4.6 Fig: Applied boundary conditions of one piece drive shaft

RESULTS

DEFLECTIONS:



4.7 Fig: Results in displacement of one-piece drive shaft in X-Direction

STRESSES:

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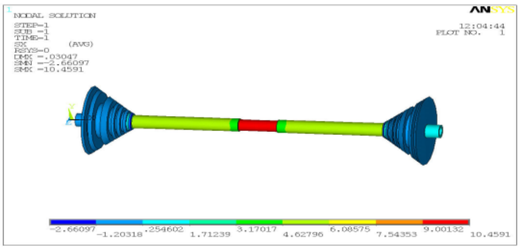
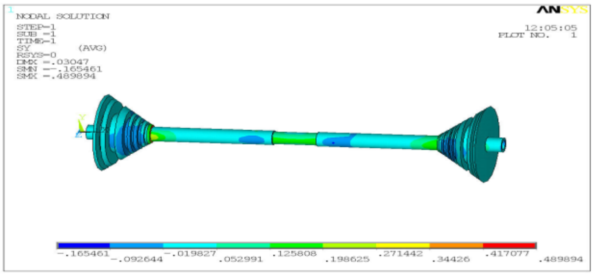


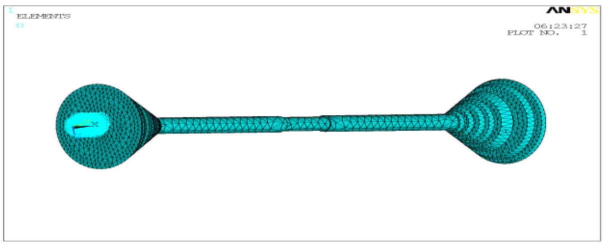
4.8 Fig: Stresses formed on one piece drive shaft in X-Direction



4.9 Fig: Stresses formed on one piece drive shaft in Y-Direction

BOUNDARY CONDITIONS:

One end of drive shaft is constrained in both linear and rotational moments.



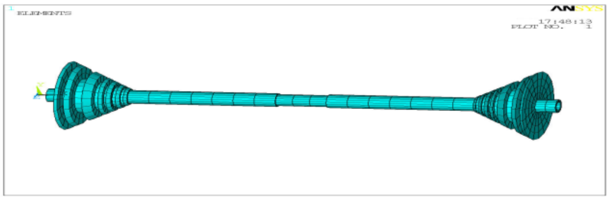
4.10 Fig. boundary conditions applied on one piece drive shaft

The mode numbers and the corresponding frequency values are shown in the below table.

The mode shapes for all the frequencies are plotted below.

MODAL ANALYSIS OF DRIVE SHAFT FOR E-GLASS/EPOXY MATERIAL:

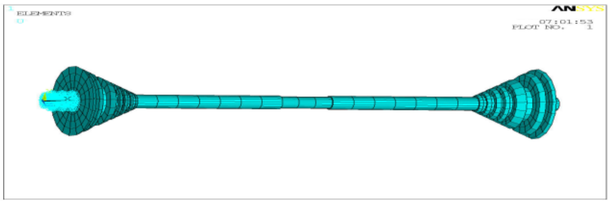
Modal analysis was carried out on drive shaft to determine the first 5 natural frequencies and mode shapes of a structure. From the modal analysis, a total of 5 natural frequencies are observed.



4.11 Fig: Finite Element Model of one-piece drive shaft

BOUNDARY CONDITIONS:

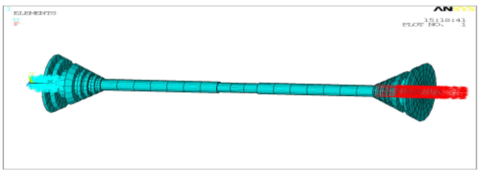
One end of drive shaft is constrained in both linear and rotational moments.



4.12 Fig. Boundary conditions applied on one piece drive shaft

HARMONIC ANALYSIS:

- A force of 2126.04 N is applied at one end of drive shaft.
- Another end constrained in all DOF.
- Drive shaft rotates with an angular speed of 125.6 rev/s.



4.13 **Fig: Boundary conditions and loading of drive shaft.**

HARMONIC ANALYSIS:

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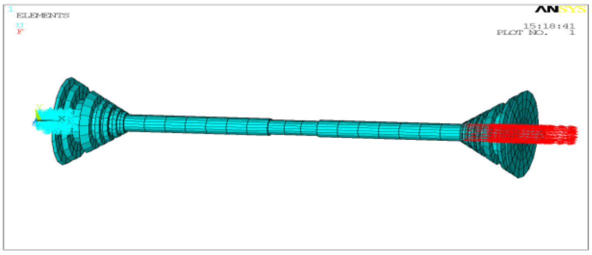
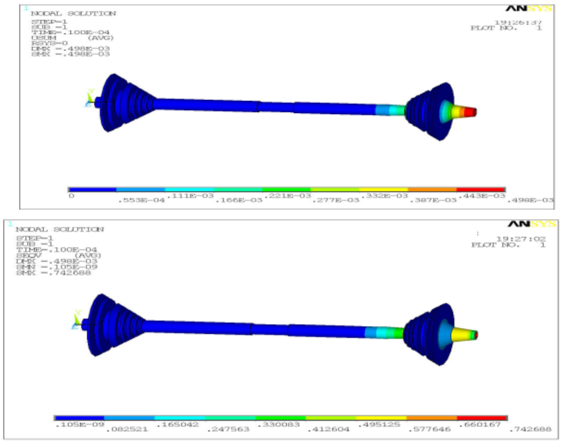


4.15 Results obtained from transient analysis of drive shaft using E-Glass/Epoxy material.

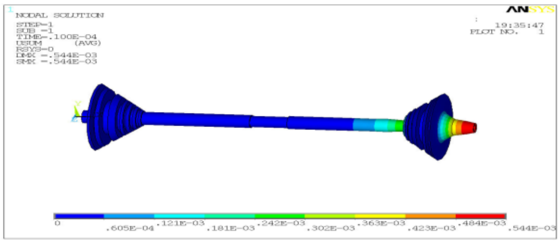
Displacements and Stresses at load step-1:

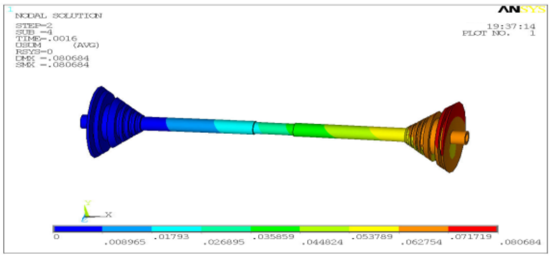


4.16 Fig: Total displacement and von misses observed on drive shaft at load step-1

Results obtained from transient analysis of drive shaft using Kevlar/Epoxy material.

Displacements and Stresses at load step-1:





4.17 Fig: Total displacement and von misses observed on drive shaft at load step-1

4.18 Fig: Total displacement and von misses observed on drive shaft at load step-11

V. RESULTS AND CONCLUSION

For estimated torque transmission in one piece drive shaft, all types of materials are supported. But Glass/Epoxy materials have frequency values more than their properties. And steel material have more ratio of von misses strength to yield strength value also this material have huge amount of weight compared to composite materials. Kevlar/Epoxy material have less ratio of von misses stress to yield strength value.

This material have frequency values less than yield strength. Kevlar/Epoxy material have less weight compare to remaining composites. At each shocking loads Kevlar/Epoxy have less ratio of von misses stress to yield stress values compare to remaining materials. So, From Analysis results, Kevlar/Epoxy material is suitable to above one-piece drive shaft.

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