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DESIGN AND ANALYSIS OF COMPOSITE DRIVE SHAFT FOR RECENT AUTOMOBILES

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Abstract— 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. This work deals with the replacement of a conventional steel drive shaft with High Strength Carbon drive shafts for an automobile application.

Keywords—composite drive shaft,carbon/epoxy shaft,weightless shaft,recent shafts.

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.

AIM AND SCOPE OF WORK

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

ANALYSIS

1. Modelling of the High Strength Carbon/Epoxy composite drive shaft using SOLIDWORKS.

2. Static, Modal and Buckling analysis are to be carried out on the High Strength Carbon/Epoxy composite drive shaft using SOLIDWORKS.

3. To calculate

a) mass reduction when using the High Strength Carbon

b) the change in deformation, stress and strain values of composite drive shaft by varying thickness of shaft

Functions of the Drive Shaft

- First, it must transmit torque from the transmission to the differential gear box.
- During the operation, it is necessary to transmit maximum low-gear torque developed by the engine.
- The drive shafts must also be capable of rotating at the very fast speeds required by the vehicle.
- 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.

DRIVE SHAFT

The term 'Drive shaft' is used to refer to a shaft, which is used for the transfer of motion from one point to another. In automotive, driveshaft is the connection between the transmission and the rear axle.

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.

Demerits of a Conventional Drive Shaft

1. They have less specific modulus and strength.

2. Increased weight.

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. Its corrosion resistance is less as compared with composite materials .

5. Steel drive shafts have less damping capacity

MERITS OF COMPOSITE DRIVE SHAFT

1. They have high specific modulus and strength.
2. Reduced weight.
3. The fundamental natural frequency of carbon fiber composite drive shaft can be twice as high as that of steel because the carbon fiber composite material has more than 4 times the specific stiffness of steel, which makes it possible to manufacture the drive shaft of 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. Due to the weight reduction, fuel consumption will be reduced .
5. They have high damping capacity hence they produce less vibration and noise.
6. They have good corrosion resistance.
7. Greater torque capacity than steel shaft.
8. Longer fatigue life than steel shaft.
9. Lower rotating weight transmits more of available power.

Design of Steel Drive Shaft

Specification of the Problem

The fundamental natural bending frequency for passenger cars, small trucks, and vans of the propeller shaft should be higher than 6,500 rpm to avoid whirling vibration and the torque transmission capability of the drive shaft should be larger than 3,500 Nm. The drive shaft outer diameter should not exceed 100 mm due to space limitations. Here outer diameter of the shaft is taken as 90 mm. The drive shaft of transmission system is to be designed optimally for following specified design requirements as shown in Table.

Sl.No.	Name	Notation	Unit	Value
1.	Ultimate Torque	Tmax	Nm	3500
2.	Max. Speed of shaft	Nmax	rpm	6500
3.	Length of shaft	L	mm	1250
4.	Outer Diameter	do	mm	90
5.	Thickness	t	mm	5

Mass of the steel drive shaft

m = ρAL

= ρ × Π/4 × (do2- di2) ×L … (1)

= 7600 x 3.14/4 x (90^2 – 80^2) x 1250

= 12.68 Kg

Torque transmission capacity of steel drive shaft

T = Ss× Π /16 × [(do4- di4) / do] … (2)

= 16.67 ×10^3 N-m

FUNDAMENTAL NATURAL FREQUENCY

The natural frequency can be found by using the two theories:

1) Timoshenko Beam theory

2) Bernoulli Euler Theory

Timoshenko Beam Theory –Ncrt

fnt= Ks (30 Π p^2) / L^2 X √ (Er^2 / 2ρ)…..(3)

Ncrt = 60 fnt"….. (4)

fnt= natural frequency base on Timoshenko beam theory, HZ

Ks = Shear coefficient of lateral natural frequency

p = 1, first natural frequency

r = mean radius of shaft

Fs = Shape factor, 2 for hollow circular cross section

n = no of ply thickness, 1 for steel shafts

1 / Ks^2 = 1 + (n^2*Π^2* r^2) / 2*L^2 * [1 + fs E / G] …. (5)

Ks= 0.986

fnt= 0.986 (30 x Π x 1) / 1250^2 x √ (210x10^3 x 85/2x 7600)

fnt = 317.3 Hz

Ncrt = 60*fnt

= 19038 rpm

DESIGN OF COMPOSITE DRIVE SHAFT

The specifications for the composite drive shaft are same as that of steel drive.

No. of layers = 5

Thickness of each layer = 1mm

Stacking sequence = 0-45-90-45-0

Mass of the Composite drive shaft

m = ρAL

= ρ × Π / 4 × (do2- di2) × L … (1)

= 1600 x 3.14/4 x (90^2 – 80^2) x 1250

= 2.669 Kg

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 Cross-Section

The drive shaft can be solid circular or hollow circular. Here hollow circular cross-section was chosen because:

1. The hollow circular shafts are stronger in per kg weight than solid circular.

2. The stress distribution in case of solid shaft is zero at the center and maximum at the outer surface while in hollow shaft stress variation is smaller. In solid shafts the material close to the center are not fully utilized.

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

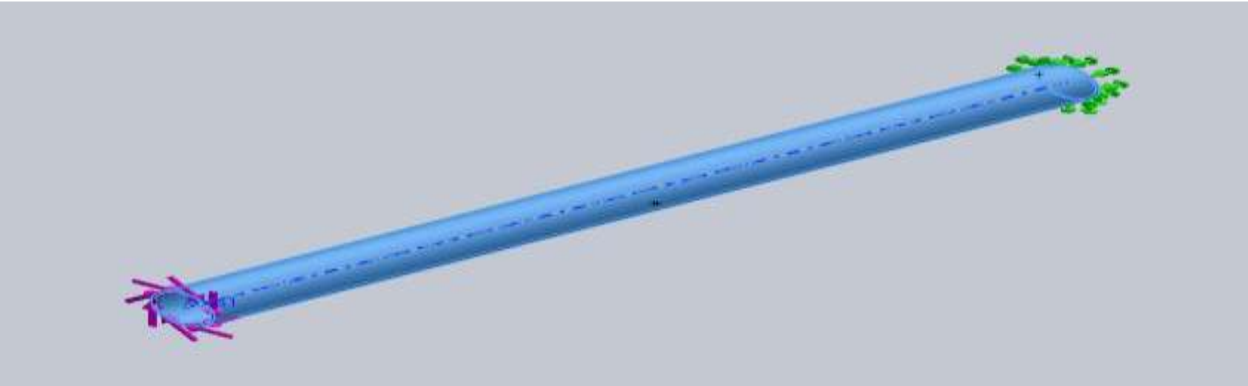

Figure1.carbon/epoxy shaft diagram

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FREQUENCY ANALYSIS RESULTS

Frequency Number	Rad/sec	Hertz	Seconds
1	1993.7	317.3	0.0031516
2	2207.2	351.28	0.0028467
3	5130.1	816.48	0.0012248

frequency values for steel shaft

Frequency Number	Rad/sec	Hertz	Seconds
1	2159.6	345.88	0.0032064
2	2382.7	382.39	0.0028786
3	5231.2	872.74	0.0012488

frequency values for carbon/epoxy shaft

Comparision of stress, strain and displacement values of carbon epoxy drive shaft with different thickness

thickness / properties	2.5mm	5.0mm	7.5mm	10mm	Steel 5.0mm
Max.stress(N/m^2)	4.74*10^8 (fails)	9.24*10^7	4.62*10^7	3.23*10^7	6.91*10^7
Min.stress(N/m^2)	5.44*10^7	4.95*10^6	2.48*10^6	2.30*10^6	2.32*10^7
Max. strain	0.00253	0.00134	0.000940	0.000734	0.000239
Min. strain	0	0	0	0	0.000034
Max. displacement (mm)	12.80	2.52804	1.92540	1.43469	1.106mm
Min. displacement (mm)	0	0	0	0	0
Weight (kg)	1.374	2.669	3.887	5.026	12.68
% Wt. Reduction	89.16	78.95	69.34	60.36	---------
No. of layers	5	5	5	5	1

CONCLUSION

a) • The usage of composite materials has resulted in considerable amount of weight saving in the range of 81% to 72% when compared to conventional steel drive shaft.

• Taking into account the weight saving, deformation, shear stress induced and resultant frequency it is evident that composite has the most encouraging properties to act as replacement to steel

References

- D.dinesh [1] done Optimum Design and Analysis of a Composite Drive Shaft for an Automobile by Using Genetic Algorithm and Ansys using Carbon/Epoxy.
- D.G. Lee [2] manufacture Drive Shaft using Carbon/Epoxy composite with aluminum and find performance of Drive Shaft.
- M.A.K. Chowdhuri [3] done Design Analysis of an Automotive Composite Drive Shaft Using Graphite/ Epoxy and Aluminum
- (Nimesh A. Patel, 2013)[4] have proposed the drive shaft of TATA-407 and the modelling of the drive shaft assembly was done using Solid works and ANSYS used for predicting analysis results. The different composite material likes, E glass, Kevlar Epoxy, boron epoxy, etc. are going to analyzed and studied here for drive shaft. E glass composite material is selected for the drive shaft. In this analysis, E- glass epoxy has less stresses (37.162 MPa) generated compared to steel material (215.3MPa) and also the objective of minimization of weight of shaft is done by using Composite materials.
- (T.Rangaswamy, 2002)[5] selected the E-Glass/Epoxy and HM Carbon/Epoxy materials for composite drive shaft. Finite element analysis is performed using ANSYS 5.4 software. To model both the composite shaft, the shell 99 element is used and the shaft is subjected to torsion. The shaft is fixed at one end in axial, radial and tangential directions and is subjected to torsion at the other end .The usage of composite materials and optimization techniques has resulted in considerable amount of weight saving in the range of 48 to 86% when compared to steel shaft.