DESIGN OPTIMIZATION OF DRIVE SHAFT FOR AN AUTOMOBILE APPLICATIONS

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Abstract

The driveshaft is a mechanical instrument that is used in automobiles. The other name of the drive shaft is driveshaft is prop shaft. It has one long cylindrical structure consist of two universal joints. By using the driveshaft it transfers the rotary motion to the differential by using the helical gearbox. By using this rotary motion the rare wheels will run. The 3dimensional Model of automobile drive Shaft is designed using CATIA parametric which enables product development processes and thereby brings about an optimum design.

Now a day’s steel is using the best material for the driveshaft. In this paper replacing the composite materials (Kevlar, e-glass epoxy) instead of steel material and it reduces a considerable amount of weight when compared to the conventional steel shaft. The composite driveshaft have high modulus is designed by using CATIA software and tested in ANSYS for optimization of design or material check and providing the best datebook

Keywords: The driveshaft, CATIA, automobile, composite materials, steel, ANSYS, Kevlar, e-glass epoxy.

I. Introduction

The term driveshaft used in SAE (society of automotive engineers) to discuss the driveshaft and it is placed between rare axle and the transmission of the assembly on a Rare-Wheel-drive vehicle. The other names for the drive shaft ade propeller shaft, prop shaft. While coming to the construction it has one cylindrical shaft and 2 or more universal joints this drive shaft has a lot of applications in automobiles and other areas. Especially this driveshaft used in vehicles like as trucks, buses, airplanes.

A driveshaft is a rotating part that transmits power from engine to rare wheels. Nowadays for manufacturing high-quality steel is using in industries. We can improve the power transmission by light Hook’s weight and reduction of inertial mass. Now a day’s there is heavy equipment for the reduction of the weight in
automobiles. The high-quality steel material is replaceable by advanced composite materials like Kevlar, E- glass, and Boron. The designer is mostly preferred composite materials why because of them have the high strength, stiffness. According to the results, whenever the high amount of torque applies on the driveshaft then that driveshaft act like a shock absorber and little amount of stress will be reduced and will increase the shaft life.

II. Methodology

Study of failure in the driveshaft
Selection of composite materials
Preparation of the CATIA model
Analysis of driveshaft with some materials and composite materials

III. Design Calculation of Drive Shaft

H-Series Ashok Leyland Engine, Truck model - 6DT120:
Max. Power (P) = 132kW
Max. Torque (T) = 660N-mm
Speed (N) = 1200-1600rpm
Length (L) = 1800mm

Steel Driveshaft (10)

Power \( P = \frac{2\pi NT}{60} \)

\[
T = \frac{P \times 60}{2N}
\]

\[
T = 132 \times 103 \times 60 / 2\pi \times 1200
\]

\[T = 1050.42 \text{ N-m}\]

From the Design datebook \( \frac{D}{d} = 1.27 \)

\[D = 1.27d\]

\[
T = \pi /16 \times \tau \times (D^4 - d^4) / d
\]

Assuming

Take \( \tau = 50 \text{ N/mm}^2 \) for steel

\[
1050.42 \times 103 = \pi /16 \times 50 \times (1.25d^4 - d^4) / 1.25d
\]

\[= 45.26 \text{ mm}\]

\[d = 46 \text{ mm}\]

\[D = 1.25 \times 46 = 58 \text{ mm}\]
L=1800mm
= angle of twist $1^\circ$ to $1.5^\circ$

$\frac{1^\circ}{180} = 0.01725\text{rad}$

$T/J = G/L$

Where

$T =$ maximum torque applied on the driveshaft (N-m)

$J =$ polar moment of inertia (mm$^4$)

$J = \frac{\pi}{32} D^4 - d^4$

$J = \frac{\pi}{32}(1.25d^4 - d^4)$

$J = 0.141d\text{ mm}^4$

$1050.42\times 103/1.141d^4$

$= 80\times 103\times 0.0172/18000$

$d= 57\text{mm}$

$D = 1.25\times 57$

$D = 71.25\text{mm}$

Where

$T =$ thickness of the hollow shaft

$t = 35-28=7$

$t = 7\text{ mm}$

The radius of shaft

$r = r_0 - r_i/2 = 35 + 28/2$

$r = 31.5\text{mm}$

$r = (r_0 + r_i)/2 = (35 + 28)/2$

$r = 31.5\text{mm}$

For long shaft the torsional buckling capacity $T_b = \tau_{cr}(2\pi^2 r t)$

Where critical stress is given by $\tau_{cr} = \frac{E/302(1 - \nu^2)^{3/4}}{(t/r)^{3/2}}$

$[207\times 103/3\nu^2(1 - 0.3^2)(7/31.5)^{3/2}]$

$\tau_{cr} = 5482.76\text{ N/mm}^2$

$T_b = 5482.76(2 \times 2905 \times 6.5)^2$
Natural Frequency: \( f_{nb} = \frac{\pi}{2} \frac{E I}{M L^4} \)

Where
\( E = \text{modulus of elasticity (pa)} \)
\( m = \text{mass per unit length (kg/m)} \)
\( L = \text{length of driveshaft (mm)} \)
\( I = \text{area moment of inertia (m}^4\text{)} \)
\( I = \frac{\pi}{16} (D^4 - d^4) \)
\( = \frac{\pi}{16} (0.074^4 - 0.056^4) \)
\( I = 6.978 \times 10^{-7} \text{m}^4 \)

\( m = \text{mass per unit length of the shaft given by} \)
\( m = \rho \frac{\pi}{4} (D^2 - d^2) \)
\( 7600 \times \frac{\pi}{4} (0.07^2 - 0.056^2) \)
\( m = 10.59 \text{ kg/m} \)

\( f_{nb} = \frac{\pi}{2} \times 210 \times 10^9 \times 6.958 \times 10^{-7} / 2.216 \times 1.8^4 \)
\( f_{nb} = 124.49 \text{ Hz} \)

IV. Static Analysis of Drive Shaft

Static Analysis

The static analysis gives the displacement, stress, strain, and force values in structure or component Caused by applied loads effects. Static analysis is used to find out the constant load effect on the component.

The model the modal the shaft is saved in the form of IGES that id imported from CATIA to ANSYS directly. Below shown type is imported to ANSYS.
Imported Model

Fig. 1: Imported model

Meshing and Boundary Conditions

Fig. 2: Boundary conditions

With 10075 number meshing was done on the structure and there are 2393 tetrahedral elements there.
Table 1: Static analysis results

| Material | Deformation (mm) | Stress (N/mm²) | Strain | Safety factor |
|----------|-----------------|----------------|--------|---------------|
| Steel    | 0.0001835       | 0.83247        | 4.6571e-6 | 1.0355        | 15            |
| Kevlar   | 4.3062e-5       | 0.14186        | 1.0624e-6 | 6.7641        | 15            |
| E glass  | 0.0019173       | 0.22475        | 4.7873e-6 | 3.8353        | 15            |
| Boron    | 3.0376e-5       | 0.28918        | 7.6592e-7 | 2.9808        | 15            |

Here, from a comparison of steel drive shaft with composite drive shaft as shown in the above table, it can be seen that the maximum deformation 0.0001835mm at steel material and corresponding deformation in Kevlar, E glass and boron are 4.3062e-5mm, 0.0019173mm, 3.0376e-5. Also, the von-misses stress in the drive shaft for steel 0.83247 MPa while in Kevlar E glass and boron the von-misses stresses are 0.14186MPa, 0.22475MPa, and 0.28918 Mpa respectively.
V. Modal Analysis of Drive Shaft

It is the one type of analysis in ANSYS and it is Modal analysis to determine the natural frequency and mode shapes of a defined structure or any other part in the designing process. Modal analysis is the study of the dynamic properties of a system in the frequency domain.

![Total Deformation 1](image1)

**Fig. 4:** Total Deformation 1 in Modal Analysis

![Total Deformation 2](image2)

**Fig. 5:** Total Deformation 2 in Modal Analysis

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According to the control plot, the maximum deformation at the propeller shaft because of two fixed yokes. The maximum deformation is 11.002mm at frequency 109Hz.

**Table 2: Modal analysis results**

| Material | Mode 1 (Hz) | Mode 2 (Hz) | Mode 3 (Hz) | Mode 4 (Hz) |
|----------|-------------|-------------|-------------|-------------|
| Steel    | 10.659      | 93.885      | 11.002      | 109         | 10.213      | 262.95      |
| Kevlar   | 24.899      | 190.27      | 25.706      | 220.97      | 23.853      | 532.22      |
| E glass  | 21.217      | 95.142      | 21.892      | 110.79      | 20.326      | 267.87      |
| Boron    | 19.072      | 243.25      | 19.673      | 281.78      | 18.268      | 682.29      |

Here, from the comparison of steel drive shaft with composite drive shaft as shown in the above table, it can be seen that the maximum deformation 24.899mm at Kevlar material and corresponding deformation in Steel, E glass and boron are 10.69 mm, 21.217mm and 19.072mm respectively.
VI. Fatigue Analysis of Drive Shaft

Fatigue analysis is a method used to finding the fatigue loads on the structure at which place that structure becomes unstable

There are two types of technics are there in the ANSYS, Mechanical, Structural and linear programs for finding the buckling load and buckling mode shapes of structure & fatigue analysis in nonlinear type and linear buckling analysis. These two methods are popularly used to get different results.

Total Deformation 1

![Figure 7: Total deformation 1 in Fatigue Analysis](image1)

Total Deformation 2

![Figure 8: Total deformation 2 in Fatigue Analysis](image2)
According to the contour plot, the maximum deformation at fixed yokes because of two fixed the yokes and minimum deformation at the propeller shaft.

The maximum deformation is 1.2295 mm at load multiplier 2.6439e+05.

Table 3: Fatigue analysis results

| Materials | Mode 1 | Load multiplier | Mode 2 | Load multiplier | Mode 3 | Load multiplier |
|-----------|--------|-----------------|--------|-----------------|--------|-----------------|
| Steel     | 1.0747 | 2.6207e+05      | 1.0735 | 2.633e+05       | 1.2295 | 2.6439e+05      |
| Kevlar    | 1.0752 | 1.054e+06       | 1.0699 | 1.0617e+06      | 1.1639 | 1.649e+06       |
| E glass   | 1.0758 | 2.6838e+06      | 1.1012 | 2.6863e+06      | 1.086  | 2.698e+06       |
| Boron     | 1.0769 | 1.7569e+06      | 1.2751 | 1.7692e+06      | 1.1250 | 1.7702e+06      |

Here, from a comparison of steel drive shaft with composite drive shaft as shown in the above table, it can be seen that the maximum deformation at mode shape 31.1639 mm at Kevlar material and corresponding deformation in Steel, E glass and boron are 1.2295 mm, 1.086mm and 1.1250mm respectively.

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V. Conclusion

According to the results, the conclusion is Kevlar composite material is the good material for the drive shaft based on the below applications and advantages

Advantages

- Kevlar has the high tensile strength at low weight.
- It has better flame resistance and low electrical conductivity.
- Kevlar also has high modulus and low thermal shrinkage.
- Kevlar has excellent dimensional stability and high chemical resistance.

Applications

- Kevlar is used in making the BATTLE HELMETS.
- In Motorcycle Safety clothing’s also Kevlar used.
- Kevlar used in the manufacturing of shoes and cycle tires.
- Manufacturing the AUDIO EQUIPMENT and Rope, Cable, Sheath also Kevlar used.
- The CHASSIS and Brakes of vehicles are manufactured by using Kevlar material.

Future Scope

By this project results, in the future, we can use composite materials by replacing steel materials. But experimental work has to done on this project like deformation, stress, and strain.

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