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Hybrid Design and Analysis of Advanced Propeller Shaft

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Abstract

Propeller shaft is a transmission system used to transmit the power from gear box to differential unit. During transmission of power vibration was produced in propeller shaft. So crack was produced in it, which produces transmission losses. In this paper ANSYS 14.5 was used to analyze the hybrid propeller shaft with structural dynamic analysis for varying the material at different speed ratio. Then the results were compared with each material and the each speed ratio, finally best results were optimized.

Keywords: Propeller shaft, Composite material, Light Weight, Structural Dynamic Analysis, and Speed Ratio.

Introduction

The function of a propeller shaft is to transmit power from one point to another in a smooth action. The shaft is designed to send torque through an angle from the transmission to the axle[1]. The propeller shaft must operate through constantly changing relative angles between the transmission and axle. It must also be capable of changing length while transmitting torque. The axle rides suspended by springs in a floating motion[2]. This means the propeller shaft must be able to change angles when going over various roads. This is accomplished through universal joints, which permit the propeller shaft to operate at different angles[3]. This design produces the smoothest running condition. An out of phase shaft can cause a vibration.

Construction Details

Typical Propeller shaft parts has following parts

- Sliding yoke
- Sliding yoke
- Pinion yoke
- CV joint coupler
- Lube fitting
- Clamp
- Output shaft
- Screw

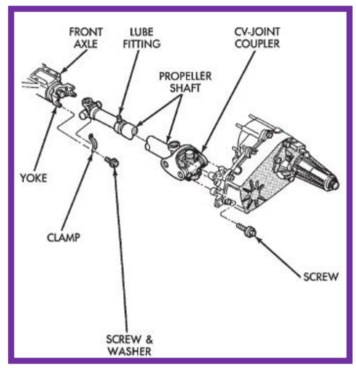

Figure.1 Configuration of typical propeller shaft

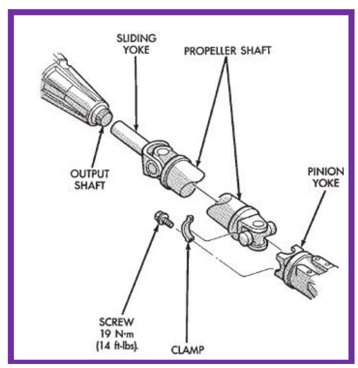

Figure.2 Configuration of typical propeller shaft

Present materials used

- Steel
- Boron/Epoxy Composite
- Kevlar/Epoxy Composite
- Aluminium – Glass/Epoxy Hybrid
- Carbon – Glass/Epoxy Hybrid

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- Titanium alloy (Ti-6Al-7Nb).

Failure Identification

Machine elements and assemblies in the cases of the two variable loads are subject to fatigue stress, which under certain circumstances can lead to fatigue fractures and ultimately machine failure. Analysis of failures caused by fractures shows that the majority of them can be attributed to material fatigue [1]. Current design processes are still based on analytical methods and standards for defining immediate strength and fatigue parameters. These methods are based on analytical and empirical solutions, which in many (geometrically or load-wise) complicated cases allow only for a rough approximation of strength characteristics. It is especially difficult to define strength parameters in notch shapes/technological notches, which leads to unavoidable design errors and thus can cause exploitation problems [1, 2].Fatigue stress research is usually either oriented towards a certain practical application or a particular theoretical fatigue analysis case and therefore generally does not take into account the fact that the analyzed construction is actually not an isolated object, i.e. that it is situated within a certain environment [3, 6]. Generally, such environment can be characterized by a given variability, which more or less affects material fatigue and therefore the exploitation conditions should match design requisites [5].

Parameters with specification

The propeller shaft system used in this analysis has the following dimensions.

- Shaft length : 61.5 cm
- Shaft diameter : 5 cm
- Joint length :5.5 cm
- Yoke length :6.
- Yoke diameter : 2.5 cm
- Max Operating Angle : 24°

Methodology

Methodology which is used in this analysis is given shown in the figure.3.

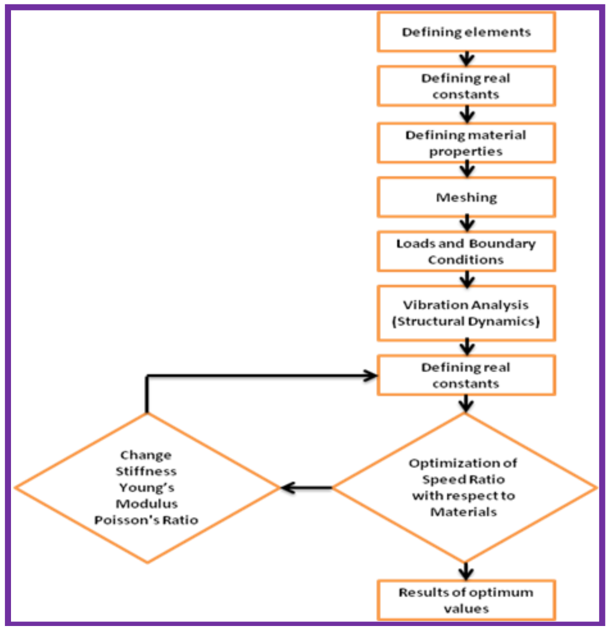

Figure.3 Methodology

Define Elements

The following hybrid propeller shaft model is created by using the modeling software solid works 2013 and its dimensions are given in the chapter 3.

Real Constants

The following real constants are used to analyze the hybrid propeller shaft

- Optimum Material – Titanium alloy (Ti-6Al-7Nb).
- Speed ratio – 60, 80,100 kms.

Material Properties

The following properties of the materials are used in this analysis.

Table.1 Material properties

S.No	Material	Density	Young's Modulus	Poisson's Ratio
01	Steel	7600	207.0	0.3
02	Aluminuam **[T6-6063]**	2700	72	0.33
03	**E-Glass Epoxy**	1980	8.02	0.24

Meshing and Boundary Conditions

In this analysis hexahedral type of mesh is used to mesh the entire structure of the hybrid propeller shaft using ANSYS 14.5 and the element

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size is 0.00125mm (fine mesh). The following figure.4 shows the entire mesh geometry.

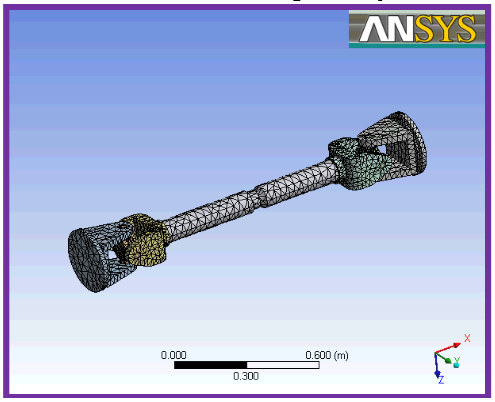

Figure.4 Mesh model

Transient Structural Analysis

The following transient structural analysis of a hybrid propeller shaft is done by using ANSYS 14.5 at different speed ratios and the results were given below.

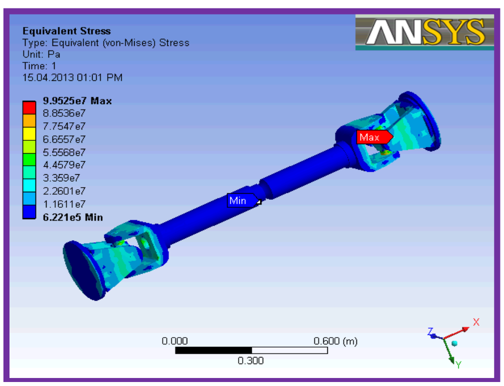

Figure.5 Equivalent Stress Distribution

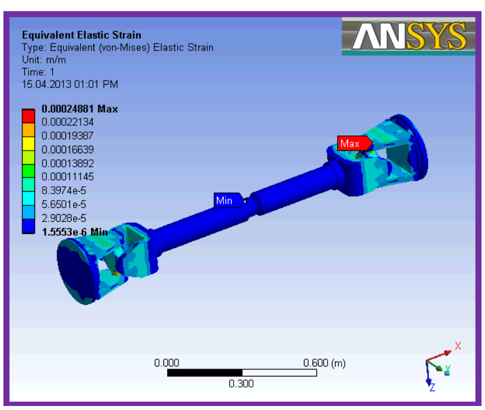

Figure.6 Equivalent Elastic strain

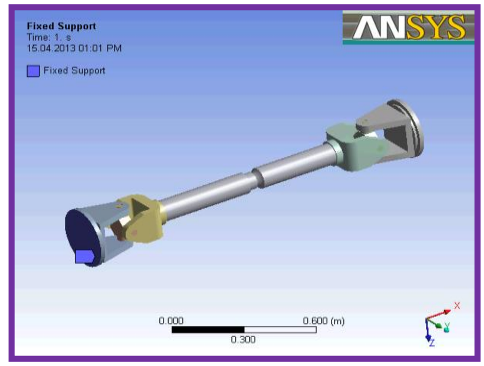

Figure.7 Fixed Support reaction

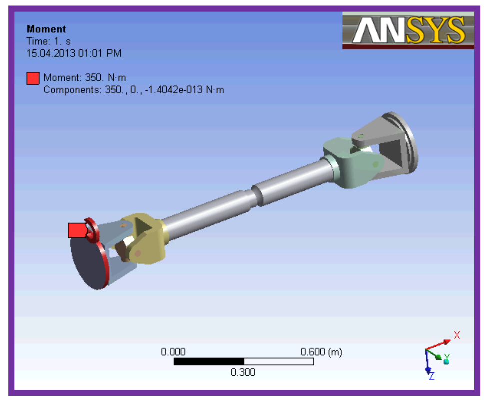

Figure.8 Moment at fixed support

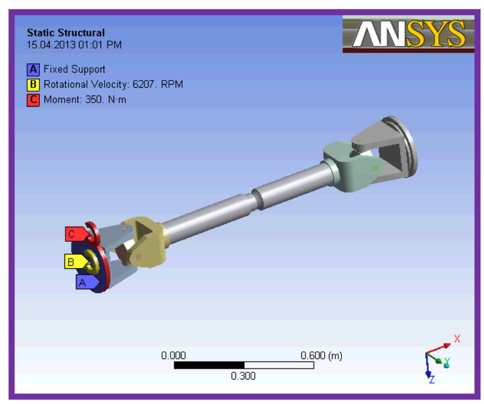

Figure.9 Static Structural Analysis

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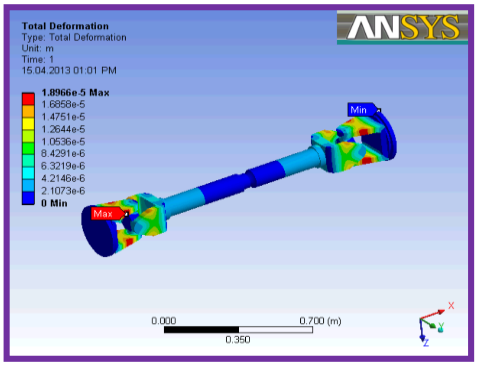

Figure.10 Total deformation

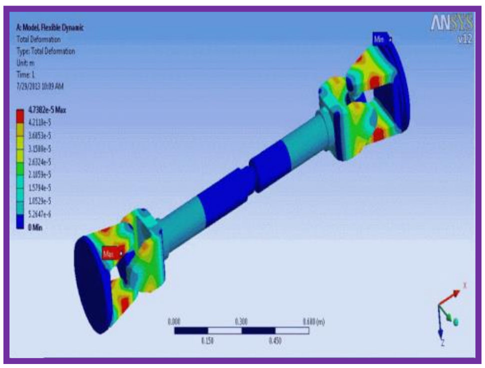

Figure.11 Flexible Dynamic Analysis

Discussions

Equivalent Stress Distribution

Fig.5 shows the equivalent stress distribution throughout the shaft. It shows that the maximum stress occurred at the right end of the shaft with the maximum value of 9.9525×10^{7} Pa and the minimum value of stress is found at the middle portion with the value of 6.221×10^{7} Pa.

Equivalent Elastic strain

Fig.6 shows the equivalent elastic strain distribution throughout the shaft. It shows that the maximum strain is occurred at the right end of the shaft with the maximum value of 0.0024881 and the minimum value of strain is found at the middle portion with the value of1.5553×10^{-6}.

Fixed Support reaction and moment

Fig.7 & 8 shows the fixed support reaction and moment of the shaft and it clearly show that the maximum moment found 350 N-m.

Static Structural Analysis

Fig.9 shows the static structural analysis of the propeller shaft at fixed moment with the rotational velocity of 6207 rpm.

Total deformation

Fig.10 shows the total deformation of the shaft. It shows that the maximum deformation is occurred at the left end of the shaft with the maximum value of 1.8966×10^{-5} and no deformation is found at the right end portion.

Flexible Dynamic Analysis

Fig.11 shows the effect of Flexible Dynamic Analysis of the shaft with total deformation. Results show the no deformation at the right end and maximum value at left end (4.7382×10^{-5} mm).

Conclusion

In this work, a one-piece hybrid aluminum/composite drive shaft for a rear wheel drive automobile was designed and manufactured ,tested and analysis by FEA have been done. Static torsion test was carried out for a hybrid aluminum glass fiber composite drive shaft. Hybrid shaft having stacking sequence [±45] with different number of layers were studied. The conclusions obtained in this numerically study are summarized as follow:

1. Failure modes of both torsion were studied .
2. Fiber orientation and number of layers strongly affect the static torsion capacity of a hybrid aluminum/composite drive shaft.
3. The torque capacity is increased for Hybrid shaft [+45/-45]. laminates, approximately 56% higher than the pure aluminum tube .
4. Increasing the number of composite layers would increase the fatigue strength for a hybrid aluminum/composite drive shaft.

The conclusions obtained in FEA analysis of full scale hybrid shaft are summarized as follow:

1. The Design Von Mises Stress obtained for hybrid drive shaft is 6 times the allowable stress.
2. Shear stress obtained for hybrid shaft is 37% higher than steel drive shaft .
3. Total deformation of the hybrid shaft is 60% less than steel drive shaft.
4. The highest bending natural frequency obtained for Hybrid shaft is 293.613 Hz (17616.78 rpm) which is 63 % higher than required bending natural frequency 108 Hz(6500rpm) .

Referance

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