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Design And Optimization Of Automobile Propeller Shaft With Composite Materials Using FEM Analysis

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Abstract- The Roadway vehicles like cars, buses, trucks and land movers having many mechanical parts in common like Engine parts, Propeller shafts, Gearbox, Brakes, Clutches, Wheels, etc., To make the vehicle fuel efficient which in result make the transportation economical, the weight of that vehicle should be reduced. Since the composite materials are light weight with more strength & stiffness, inclusion of composite materials to conventional steel materials used in auto parts will reduce the weight and improve the mechanical properties of those components. This paper deals with propeller shaft of heavy vehicle to design the shaft for its minimum dimensions to satisfy current problem specification and then replace conventional steel material with composite material. The design of the propeller shaft is first theoretically designed for steel, Carbon/Epoxy and Glass/Epoxy composite material for its safe dimensions. Then they can be created as a part model for respective dimensions in CREO software. After modeling, Torsional buckling analysis can be carried out in the propeller shafts using Ansys software to check whether theoretical calculations and analytical results are similar. Then obtained results are compared among those three materials and Carbon/Epoxy composite material is selected as suitable replacement material for conventional steel material in terms of several mechanical properties.

Keywords: Propeller Shafts, Ansys ,Solidworks, Analysis, Composite Material, Conventional Steel, Mechanical Properties

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, 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. Drive shafts are used in automotive, aircraft and aerospace applications. The automotive industry is exploring 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.

Composite material

A composite material is produced by combining two or more materials at a macroscopic level, not soluble in each other to achieve some superior properties. Many of the materials which we see around us are composites. Some of them like wood, stone, etc. are natural composites, as they are developed by natural processes. Wood is a fiber material consisting of thread-like hollow elongated organic cellulose that normally constitutes about 60-70% of wood of which approximately 30-40% is crystalline, insoluble in water, and the rest is amorphous and soluble in water. Cellulose fibers are flexible but possess high strength. The more closely packed cellulose provides higher density and higher strength. The walls of these hollow elongated cells are the primary load-bearing components of trees and plants. When the trees and plants are live, the load acting on a particular portion (e.g., a branch) directly influences the growth of cellulose in the cell walls located there and thereby reinforces that part of the branch, which experiences more forces.

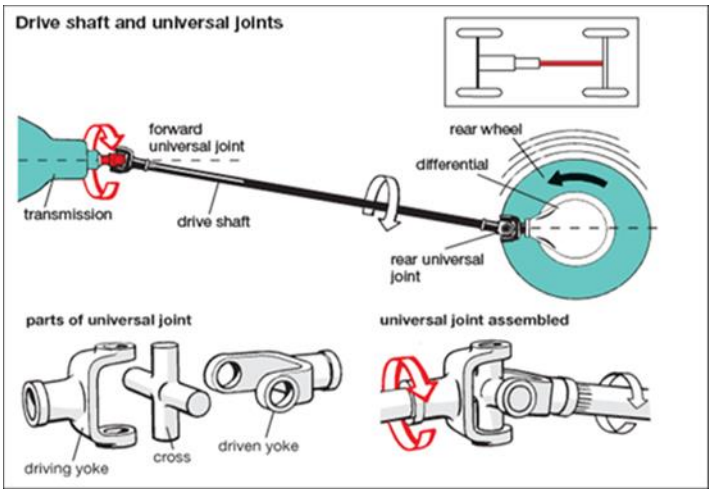

Fig: Drive shaft and Universal Joint

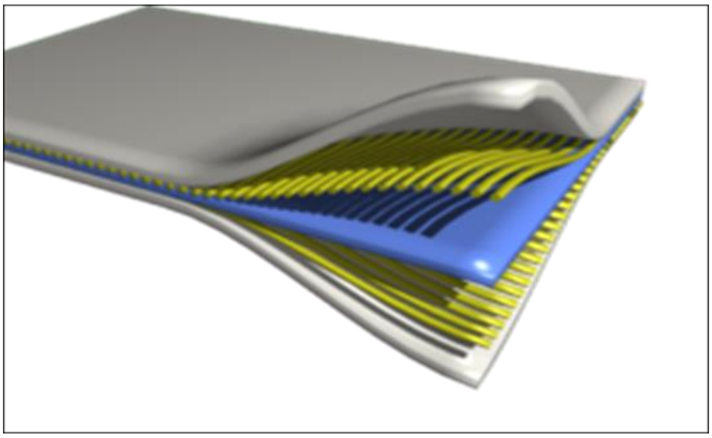

Fig: Illustration of Composite material

Related Work-

[1] Deepti kushwaha & Gaurav Saxena "Optimal Design and Analysis of Composite Drive Shaft for a Light Commercial Vehicle" International Journal of Advance Engineering and Research Development pp 107-113 Aug

They investigate that the weight reduction of the drive shaft can have a certain role in the general weight reduction of the vehicle and are a highly desirable goal. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This present work includes, modelling and analysis of both the steel and composite drive shaft by changing in diameter have been done using Pro-E and ANSYS 12.1 software and concludes that the use of composite materials for drive shaft would induce less amount of stress which additionally reduces the weight of the vehicle.

[2] Amol B Rindhe and S R Wagh "Failure Analysis And Evaluation Of A Composite Material Automotive Driveshaft By Using Fem—A Review" Int. J. Mech. Eng. & Rob. Res. ISSN 2278 – 0149 Vol. 3 No. 2 April 2014.

They investigate heavy duty vehicles driveshaft is one of the important components. Generally a two-piece alloy steel drive shaft is used in automotive which can be replaced by a single piece of composite material driveshaft. Our main aim is to study its design procedure along with finite element analysis some important parameter will be obtained. The composite drive shaft made up of high modulus material is designed by using CAD software and tested in ANSYS for optimization of design or material check and providing a best material.

[3] R. Srinivasa Moorthy, at el Yonas Mitiku & K. Sridhar " Design of Automobile Driveshaft using Carbon/Epoxy and Kevlar/Epoxy Composites" American Journal of Engineering Research e-ISSN: 2320-0847 P-ISSN: 2320-0936 Vol. 2, Issue-10, pp 173-179 (2013).

They Use of advanced composites has resulted in remarkable achievements in many fields including aviation, marine and automobile engineering, medicine, prosthetics and sports, in terms of improved fatigue and corrosion resistances, high specific strength and specific modulus and reduction in energy requirements owing to reduction in weight. The aim of this work is to replace the conventional steel driveshaft of automobiles with an appropriate composite driveshaft.

THEORETICAL DESIGN:

TORSION:

In the field of solid mechanics, torsion is the twisting of an object due to an applied torque. It is expressed in Newton meters (Nm). In sections perpendicular to the torque axis, the resultant shear stress in this section is perpendicular to the radius.

For shafts of uniform cross-section the torsion is:

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L} \qquad \dots\dots eqn\ 1$$

Where,

- T is the applied torque or moment of torsion in Nm.
- $\tau$is the maximum shear stress at the outer surface
- r is the distance between the rotational axis and the farthest point in the section (at the outer surface).
- L is the length of the object the torque is being applied to or over.
- θ is the angle of twist in radians.

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- *G* is the shear modulus, also called the modulus of rigidity, and is usually given in Gigapascals (GPa).

Design of Shaft Conventional Steel Shaft

Automotive shafts are manufactured by forging process. This means that the propeller shaft meets its rated strength and has required ductility and fatigue properties. The reliability and consistency in the properties of the shaft is required because of the nature of the application.

Propeller shafts are designed on the basis of torsional loading. The commonly used materials for manufacturing the propeller shaft is low carbon steel with 10-18 % Chromium and 5-8 % Nickel. The strength of the material used for manufacturing propeller shaft is:

Yield Strength (Syt) = 370 N/mm^2

Table .Mechanical Properties of Steel

Mechanical Properties	Symbol	Units	Steel
Young's Modulus	E	GPa	207
Shear Modulus	G	Gpa	80
Poisson's Ratio	M	-	0.3
Density	P	Kg/m^3	7600
Yield Strength	Sy	MPa	370

Materials for selection

Sr. No.	Materials	Density Kg/M^3	Yield Strength Mpa
1	Steel	7850	1380
2	Aluminium	2710	276
3	Carbon Fibre	1550	3220
4	Glass Fibre	2100	3400
5	Graphite Fibre	3500	3500

DESIGN OF COMPOSITE SHAFT

Similar to steel shaft all the calculations also performed on the GFRP material which is proposed as the alternative material for the steel, and following design table is obtained.

Table . Properties of material

Sr. No	Properties of Material	Glass Fiber
1.	Tensile Modulus along X-direction (MPa)	34000
2.	Tensile Modulus along Y-direction (MPa)	6530
3.	Tensile Modulus along Z-direction (MPa)	6530
4.	Compressive Strength of material (MPa)	450
5.	Poisson's ratio	0.217
6.	Mass Density of the material (g/cm^3)	1.4

FINITE ELEMENT METHOD

The Finite Element method is a numerical method, which can be used for accurate solution of complex engineering problems. The method was first developed in 1956 for the analysis of aircraft structural problems. Thereafter, within a decade, the potentialities of the method for the solution of different types of applied science and engineering problems were recognized. Over the years, the finite element technique has been so well established that today it is considered to be one of the best methods for solving a wide variety of practical problems efficiently.

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Fig: Meshed Model for Propeller shaft Structural steel assembly with 25 mm Mesh Size

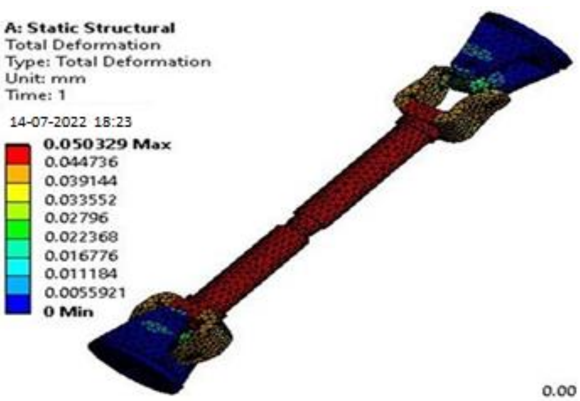

Fig: Total Deformation Plot (mm) for conventional steel Shaft

Fig: von Mises Stress Plot (MPa) for conventional steel shaft

CONCLUSIONS

- We have calculated 72 mm as outer diameter of the steel shaft and 65.6 mm which passes the acceptance criteria in FEA chapter.
- Composite shaft made up of GFRP material can be used to replace the conventional steel shaft in the given application successfully.
- Weight of the shaft is reduced by 28 % when composite shaft is used instead of conventional hollow steel shaft as propeller shaft of the given vehicle is observed.
- The manufactured composite shaft successfully withstood the torque which will be applied in the application.

Mechanism safe takes the loads converts it to motion energy max stress obserb in 10. CFRP0°, CFRP90° Composite value & max Deformation obserb in 10. CFRP0°, CFRP90°.

The Carbon Epoxy and Glass Epoxy composite propeller shafts are designed to meet safe design requirements as the conventional steel shaft. From analysis Shear stress, Von-Mises stress, critical speed, Displacement, bending natural frequency and weight are determined. On mises stress of Carbon Epoxy and Glass Epoxy drive shaft are under their safe values so fracture will not occur. Shear stress of Carbon Epoxy is nearly equal to Conventional Steel shaft. The usage of composite material drive shaft has resulted in inconsiderable amount weight saving in the range of 73 to 80% when compared to conventional steel shaft. Composite materials have higher specific stiffness to provide the required strength against less weight. Higher stiffness of composite material solves the problem of higher strength requirement for drive shaft and less weight solves the problem of inertia. By reducing weight of propeller shaft, tyre wear will minimize, stability of vehicle body will increased, as the vehicle weight will be reduced. Light weight vehicle will greatly decreases the Co2 production. Apart from being lightweight, the use of composites also ensures less noise and vibrations.

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Deflection is less in Carbon Epoxy shaft as compared to Glass Epoxy shaft. This study leaves wide scope for future investigation. It can be extended to newer composite using other reinforcing phases. The reduction in weight gives further advantage in the increases in the fuel economy of vehicle.

Since this work relies on pure theoretical calculation and simulation in analysis software, the future work is to fabricate the propeller shaft in Carbon/Epoxy composite material and test it in real time environment.

Reference- [1] Deepti kushwaha & Gaurav Saxena "Optimal Design and Analysis of Composite Drive Shaft for a Light Commercial Vehicle" International Journal of Advance Engineering and Research Development pp 107-113 Aug

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