Analysis of tortional stiffness of an automobile drive shaft by composite material with FEA

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***Abstract*: The main aim of this work is to accomplish FEM analysis and to optimize the design with composite materials of drive shaft. Steel shaft is common component used in all kinds of power transmission system. Steel shaft are used due to higher durability. Substitute's metallic structure with composite can help in achieving higher stiffness and light weight components. For that it has been tried to identify suitable composite material which may the alternates in place of steel material. This form basis of replacement of steel shaft with carbon epoxy reinforced steel shaft. Steel shaft with reinforced epoxy was manufactured by taking the dimension of steel shaft as for the material and then reinforcement is done over it. The FEM analysis have been done on above material to get the material as an alternate in place of conventional steel shaft material and result are discussed.**

Index Terms: Drive Shaft, Carbon Fiber, CATIA, FEA, Torsion Test.

I. INTRODUCTION

Carbon fibers fibers about 5–10 micro meters in diameter and composed mostly of carbon atoms. Carbon fibers have several benefits including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made carbon fiber very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, carbon fibers are more expensive when compared with similar fibers, such as glass fibers or plastic fibers. To produce a carbon fiber, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fiber as the crystal alignment gives the fiber high strength-to-volume ratio. Several thousand carbon fibers are bundled together to form a tow, which may be used by itself or woven into a fabric.Carbon fibers are mainly combined with other materials to form a composite. When impregnated with a plastic resin and baked it forms carbon-fiber-reinforced polymer which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. Carbon fibers are also composited with other materials, such as graphite, to form reinforced carbon-carbon composites, which have a very high heat tolerance.

Carbon fiber is most commonly used to reinforce composite materials, particularly the class of materials known as carbon fiber or graphite reinforced polymers. Non-polymer materials can also be used as the matrix for carbon fibers. Due to the formation of metal carbides and corrosion considerations, carbon has seen limited success in metal matrix composite applications. Reinforced carbon-carbon (RCC) consists of carbon fiber-reinforced graphite, and is used structurally in high-temperature applications. The fiber also finds use in filtration of high-temperature gases, as an electrode with high surface area and impeccable corrosion resistance, and as an anti-static component. Molding a thin layer of carbon fibers significantly improves fire resistance of polymers or thermo set composites because a dense, compact layer of carbon fibers efficiently reflects heat. The increasing use of carbon fiber composites is displacing aluminum from aerospace applications in favor of other metals because of galvanic corrosion issues.

Carbon fiber reinforced polymer, carbon fiber reinforced plastic, or carbon fiber reinforced thermoplastic, is an extremely strong and light fiber-reinforced plastic which contains carbon fibers. Carbon fiber reinforcement can be expensive to produce but are commonly used wherever high strength-to-weight ratio and stiffness are required, such as aerospace, superstructure of ships, automotive, civil engineering, sports equipment, and an increasing number of consumer and technical applications. The binding polymer is often a thermo set resin such as epoxy, but other thermo set, such as polyester, vinyl ester, or nylon, are sometimes used. The composite material may contain Kevlar, Twaron, ultra-high-molecular-weight polyethylene aluminum, or glass fibers in addition to carbon fibers. The properties of the final CFR product can also be affected by the type of additives introduced to the binding resin. The most common additive is silica, but other additives such as rubber and carbon nano tubes can be used.

LITERATURE REVIEW

Hanhua Zhu An appropriate assessment of the dynamic behavior of a ship's marine propeller shaft is essential to enable the optional power delivery to the propeller and to minimize various vibrations during the rotation. As the mechanism of coupled transverse-tortional vibrations for the shaft is not fully revealed, which seriously affect the stability and reliability of ship's navigation. An accurate and applicable numerical model for the coupled vibrations of marine propeller shaft is thus proposed to solve this problem. This non-linear model with ordinary differential equations is analytical calculated on the basis of high order Runge-Kutta method. Experiments are conducted to validate the applicability of the proposed model through the comparison with numerical calculation, over a range of rotational speeds. The impact factors including eccentricity of cross section, damping coefficient and length-diameter ratio are discussed by comparing the Poincare surface of section. And the influence on the transient accelerations of the coupled vibrations are investigated in detail. The optimized design for marine propeller shaft is thus realized based on the adjustment of the unbalance quantity and structural dimension [1].

Hongxing Hua A dynamic model to study the coupled longitudinal and transverse vibrations of a submarine elastic propeller-shaft-hull system is developed using the FRF-based sub structuring method (FBSM). The total system is firstly modeled as two substructures: the elastic propeller-shaft subsystem and the hull shell. For the former substructure, the elastic propeller is modeled by using harmonic blade array elements and the shafts are assumed to be Timoshenko beams, while the latter one is modeled using traditional finite element method. After that, the two substructures are synthesized using FBSM. The modes, the natural frequencies and the coupled longitudinal and transverse vibration characteristics of the propeller-shaft subsystem, the hull shell, and the total system are analyzed. An experiment studying the dynamic characteristics of a large-scale submarine experimental setup is processed and compared with the numerical results, which shows great consistency. Finally, a further discussion is carried out focused on how the bearing stiffness affects the coupled vibration characteristics of the total system [2].

A. Sitticharoenchai Failure analysis of metal alloys propeller shaft used in marine has been carried out. The shaft fractured at shoulder with evidence of torsional-bending fatigue. Chemical composition, micro-structural characterization, fractography, hardness measurements, and finite element simulation were used for the analysis. Fatigue crack has initiated at the shoulder. The geometry of the fillet also promoted the initiation crack because the fillet was erroneously designed. It was concluded that all these factors produced fatigue failure. It is recommended to first guarantee the chemical composition and microstructure of the material. Secondly, use x111-T5-K4 flux cored wire additions in welding repair process to extend service life and, finally, accomplish the geometric parameters recommended by the standard to avoid high stress concentration factors [3].

Zhushi Rao At present, most studies on the hydro elastic analysis of marine propellers do not consider the effect of the shaft. So in this paper, with consideration of the effect of the shaft and bearings, a fluid–structure interaction model of the marine propeller is established by coupled boundary element method (BEM) and finite element method (FEM). The hydro elastic performance of the propeller is discussed with and without consideration of the shaft and bearings. The research shows that the natural frequencies of the blade attached at the shaft are slightly less than those without shaft. This would be more prominent as the shaft's flexibility is increased. There are some errors for the hydro elastic performance of propellers if the shaft and bearings are ignored. So the shaft should not be neglected in the prediction of the propellers' hydro elastic performance [4].

Yegao Quet al. This paper investigates the structural and acoustic responses of a coupled propeller shafting and submarine pressure hull system under different propeller force excitations. The entire system, which consists of a rigid propeller, a main shaft, two bearings and an orthogonally stiffened pressure hull, is submerged in a heavy fluid. The shaft is elastically connected to the pressure hull by a radial bearing and a thrust bearing. The theoretical model of the structural system is formulated based on a modified variational method, in which the propeller, the main shaft and the bearings are treated as a lumped mass, an elastic beam and spatially distributed spring-damper systems, respectively. The rings and stringers in the pressure hull are modeled as discrete structural elements. The acoustic field generated by the hull is calculated using a spectral Kirchhoff-Helmholtz integral formulation. A strongly coupled structure-acoustic interaction analysis is employed to achieve reasonable solutions for the coupled system. The displacement of the pressure hull and the sound pressure of the fluid are expanded in the form of a double mixed series using Fourier series and Chebyshev orthogonal polynomials, providing a flexible way for the present method to account for the individual contributions of circumferential wave modes to the vibration and acoustic responses of the pressure hull in an analytical manner. The contributions of different circumferential wave modes of the pressure hull to the structural and acoustic responses of the coupled system under axial, transversal and vertical propeller forces are investigated. Computed results are compared with those solutions obtained from the coupled finite element/boundary element method. Effects of the ring and the bearing stiffness on the acoustic responses of the coupled system are discussed [5].

PROBLEM STATEMENT

For the drive shaft we required high tortional stiffness to sustain the system. The existing drive shaft is metallic structure so we have to overcome this we use composite material shaft. In this work analyzing composite drive shaft for induces structural stresses and deformation in CAE software. After that, we take tortional test on Steel shaft and Composite shaft for analysis on tortional testing machine.

OBJECTIVES

1. Investigation the existing material of drive shaft
2. Suggesting the suitable composite material to overcome
3. Preparing epoxy reinforced steel shaft.
4. Analyzing for stresses, deformation and reaction moments on composite shaft.
5. Experimental testing on Torsion Testing Machine and correlating results.
6. Compare the results.

METHODOLOGY

Step 1: - I started the work of this project with literature survey. I gathered many research papers which are relevant to this topic. After going through these papers, I learnt about Reinforcement & Analysis of drive shaft.
Step2: - After that the components which are required for my project are decided.

Step 3: - After deciding the components, the 3 D Model and drafting of both steel and carbon fiber shaft was drawn with the help of CATIA software.
Step 4: - The Analysis of both the components was done with the help of ANSYS using FEA.
Step 5: - The experimental observations was taken by Torsion Test and take results of both shafts.
Step 6: - Comparative analysis of Reaction forces will be made between simulation and experimental results and then Results and conclusions will be conclude.

DESIGN CALCULATIONS

We are considering the Propeller shaft of Maruti 800 Car.
Maximum Torque = 180 Nm = 180*1000Nmm
Speed = 1440-1500 RPM
Material of Propeller Shaft = Mild Steel
Consider, Length of shaft = 400mm

According to tortional rigidity diameter of shaft is given by-
$D = (584*M_t*L/G*\theta)^{1/4}$
M_t = 180Nm = 180*1000Nmm
Modulus of Rigidity= G = 79300 N/mm^2
Angle of Twist = θ = 180 degree = π rad
By putting all the values in above equation i.e. in torsional rigidity,
$D = \left(\frac{584*180*1000*400}{\pi*79300}\right)^{0.25}$
D = 20.27mm
But, next standard size available in market is D = 22mm

STATIC ANALYSIS

FINITE ELEMENT ANALYSIS: DESIGN OF EXISTING SUSPENSION CONTROL ARM IS DONE BY USING CAD PACKAGE CATIA V5 AS PER FOLLOWING;

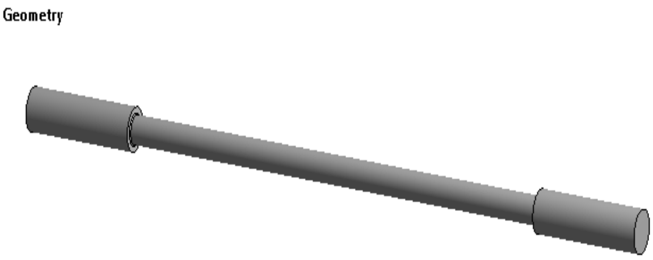


Fig. 1 CATIA model of Steel Shaft

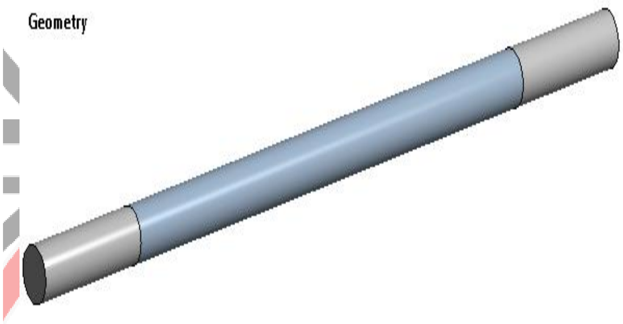
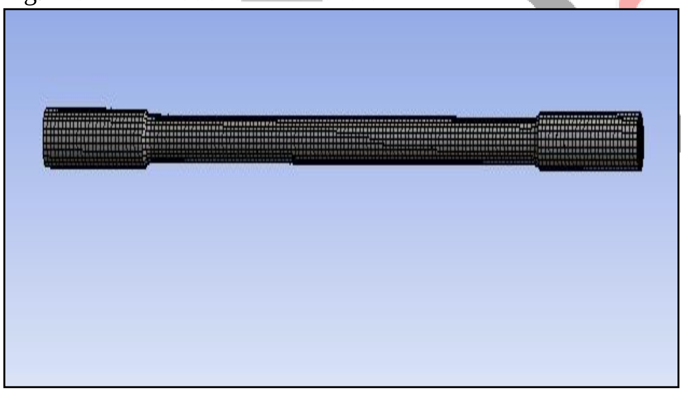
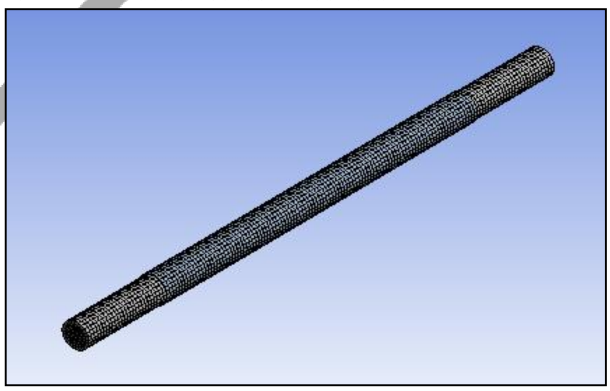


Fig. 2 CATIA Model of Carbon Fiber Shaft



Statistics	
Nodes	9695
Elements	9900

Fig.3 Meshing of Steel Shaft



Statistics	
Nodes	15946
Elements	15585

Fig. 4 Meshing of Epoxy Shaft

Boundary Condition

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both.The main types of loading available in FEA include force, pressure and temperature. These can be applied to points, surfaces, edges, nodes and elements or remotely offset from a feature.The way that the model is constrained can significantly affect the results and requires special consideration. Over or under constrained models can give stress that is so inaccurate that it is worthless to the engineer. In an ideal world we could have massive assemblies of components all connected to each other with contact elements but this is beyond the budget and resource of most people. We can however, use the computing hardware we have available to its full potential and this means understanding how to apply realistic boundary conditions.

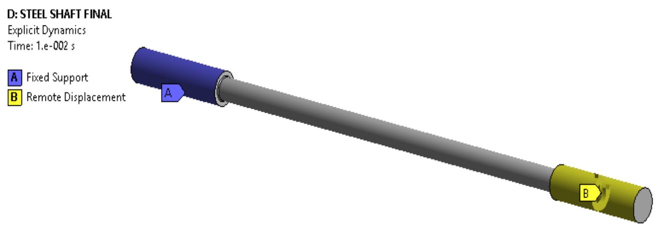
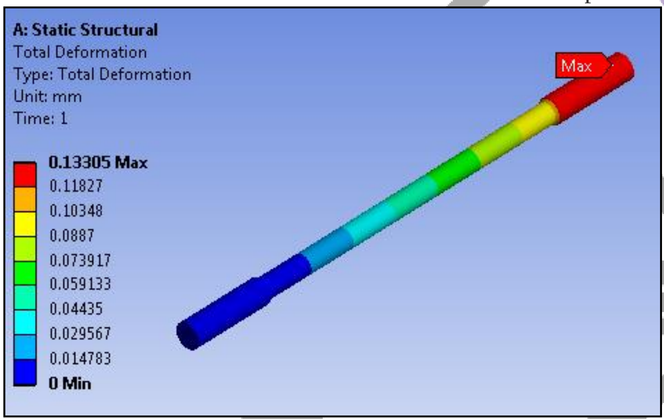


Fig.5 Boundary Condition of Steel Shaft Fig.6 Boundary Condition of Carbon Fiber Shaft

Total Deformation

The total deformation & directional deformation are general terms in finite element methods irrespective of software being used. Directional deformation can be put as the displacement of the system in a particular axis or user defined direction. Total deformation is the vector sums all directional displacements of the systems.



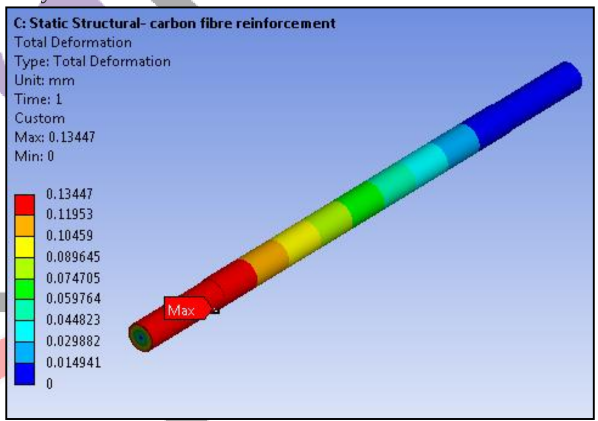


Fig. 7 Total Deformation of Steel Shaft Fig. 8 Total Deformation of Carbon Fiber Shaft

Experimental Testing

Torsion tests twist a material or test component to a specified degree, with a specified force, or until the material fails in torsion. The twisting force of a torsion test is applied to the test sample by anchoring one end so that it cannot move or rotate and applying a moment to the other end so that the sample is rotated about its axis. The rotating moment may also be applied to both ends of the sample but the ends must be rotated in opposite directions. The forces and mechanics found in this test are similar to those found in a piece of string that has one end held in a hand and the other end twisted by the other.

Fig. 9 Torque testing value of Steel Shaft Fig. 10 Steel shaft after testing

Fig.11Carbon Fiber Shaft after test

RESULTS & CONCLUSION

SR.NO.	CHARACTERISTICS	STEEL SHAFT	CARBON FIBRE
1.	Total Deformation (mm)	14.41	12.73
2.	Equivalent stress (MPa)	692.32	1455.1

From the testing results, we get the torque values. The torque required for steel shaft is 3.99Nm and that for the Epoxy Carbon Fiber shaft is 13.06Nm. So, the torque required for carbon fiber shaft is more. So, the Strength of the carbon fiber shaft is more than that of the steel shaft.
As the shaft breaks at same location in Testing & in Analysis also the results validate.

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