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DESIGN AND ANALYSIS OF COMPOSITE DRIVE SHAFT

A.Sridhar[1], Dr. R. Mohan[2], R.Vinoth Kumar[3]

[1]PG Scholar Department – Product Design and Development, Senior Faculty Department of Mechanical Engineering, Sona College of Technology, Salem-636005, Tamil Nadu

[3]Mechanical Faculty in Knowledge Institute of Technology, Salem

ABSTRACT

Almost all automobiles which correspond to design with Rear wheel drive and front engine installation have transmission shafts. In heavy duty vehicles driveshaft is one of the important components. 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, it can be achieved without increase in cost and decrease in quality and reliability. The aim of this work is to replace the conventional steel driveshaft of automobiles with an appropriate composite driveshaft. The conventional drive shafts are made in two pieces for reducing the bending natural frequency, whereas the composite shafts can be made as single-piece shafts, thus reducing the overall weight. The design parameters were optimized with the objective of minimizing the weight of composite drive shaft. 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. The replacement of composite materials can results in considerable amount of weight reduction if compared to conventional steel shaft.

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Keywords: Drive shaft, Universal joint, Modeling, Composite, Weight reduction, ANSYS.

1. INTRODUCTION

Drive Shaft is a rotating shaft that transmits power from the engine to the differential gear of a rear wheel drive vehicles Driveshaft must operate through constantly changing angles between the transmission and axle. Automotive drive Shaft is a very important component of vehicle. The present project focuses on the design of such an automotive driveshaft by composite materials. Now a day's two pieces steel shaft are used as drive shaft. However, the main advantages of the present design are only one piece of composite driveshaft is possible that fulfill all the requirements of drive shaft. The basic requirements considered here are torsion strength, torsion buckling and bending natural frequency. An optimum design of the draft shaft is done, which is cheapest and lightest but meets all of the above high load is the most requirements.

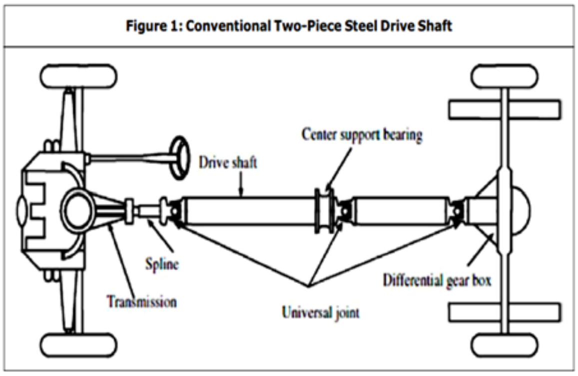

Fig:1 Conventional two piece steel drive shaft

Drive shafts are used as power transmission tubing in many applications, including cooling towers, pumping sets, aerospace, trucks and automobiles. In the design of metallic shaft, knowing the torque and the allowable shear stress for the material, the size of the shaft's cross section can be determined. In the today's days there is a heavy requirement for lightweight materials vehicle. (Fig:1&2)

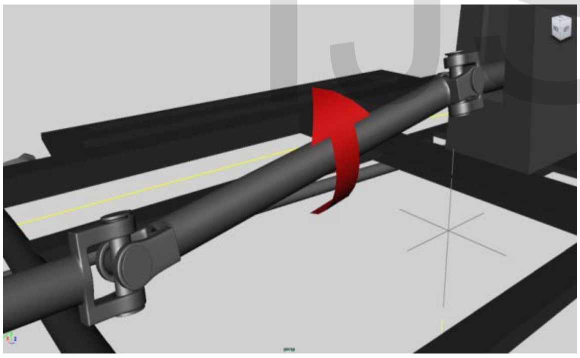

Fig:2 *3D* Model of a drive shaft

A.R. Abu Talib, Aidy Ali, Mohamed A. Badie , Nur Azida Che Lah, A.F. Golestaneh investigated about hybrid, carbon/glass fiber-reinforced, epoxy composite automotive drive shaft. They found that changing carbon fibers winding angle from 0^o to 90^o, the loss in the natural frequency of the shaft is 44.5%, while, shifting from the best to the worst stacking sequence, the drive shaft causes a loss of 46.07% in its buckling strength. The best fiber orientation angle for maximum buckling strength is 90^o[2]. Shaw D, Simitses DJ, Sheinman I investigated about Imperfection sensitivity of laminated cylindrical shells in torsion and axial compression. They found that the linear is considered satisfactory in comparison with nonlinear analysis due to that cylindrical shells under torsion are less sensitive to imperfections [3]. H.B.H. Gubran investigated about Dynamics of hybrid shafts and he found that Depending on E1/q ratio for metals and fiber angle for composites, the natural frequencies of hybrid shafts can be optimally placed [4]. Ercan Sevkat, Hikmet Tumer, investigated about Residual torsional properties of composite shafts subjected to impact loadings. They found that the Carbon reinforced composite shaft had the highest; glass reinforced composite had the lowest resistance to impact. Resistance of hybrid composite shafts was between that of glass and carbon [5]. H. Bayrakceken, S. Tasgetiren, I. Yavuz, investigated about two cases of failure in the power transmission system on vehicles: A universal joint yoke and a drive shaft, they concluded that failures are occurred as a result of fatigue process [6]. R. Srinivasa Moorthy, Yonas Mitiku & K. Sridhar investigated about Design of Automobile Driveshaft Carbon/Epoxy and Kevlar/Epoxy Composites. They found that use of Carbon/Epoxy results in a mass saving of 89.756% when compared to the conventional SM45C steel driveshaft, Obviously, the number of plies needed for Carbon/Epoxy is 14 with 1.82 mm wall thickness as compared to 44 plies with 5.72 mm wall thickness in the case of Kevlar/Epoxy [7]. Harshal Bankar, Viraj Shinde, P.Baskar investigated about Material Optimization and Weight Reduction of Drive Shaft Using Composite

Material.Young[8]. Ali S. Hammood, Muhannad Al-Waily, Ali Abd. Kamaz investigated about Effect of fiber orientation on fatigue of glass-fiber reinforcement epoxy composite material they found that fatigue strength of composite material decreasing with increasing the fiber orientation angle due to decreasing module of elasticity (strength) of composite materials. Number of fatigue cycle decreasing with increasing the fiber orientation angle, maximum at fiber angle (0^o) and minimum at fiber angle (90^o). The magnitude of fatigue strength and number of cycle of fatigue for composite material are decreasing with increasing fiber orientation angle, increasing with increasing the strength of composite material and decreasing with decreasing the strength of composite materials. For oblique load on fiber direction, surface fatigue perpendicular on fiber direction [9].Ban. Bakir and Haithem . Hashem investigated about Effect of Fiber Orientation for Fiber Glass Reinforced Composite Material on Mechanical Properties they found that the effect on hardness of the materials having different orientations of fiber and it is maximum in discontinuous fiber specimen, with orientation 90°, with orientation 0°, then with orientation 45° parallel orientation and still constant in specimen of angle 45 °. while for 0° fiber orientation angle of glass fibers/ epoxy specimens, failure was irregular and cracks propagate in the different directions [10]. B Stanly Jones Retnam, M Sivapragash and P Pradeep investigated about Effects of fiber orientation on mechanical properties of hybrid bamboo/glass fiber polymer composites they concluded that the hybrid specimen with ±45^o orientation yielded a tensile strength of 92.26 N/mm2, flexural strength of 387.725 N/mm2 and which was higher when compared with others. The hybrid specimen with ±45^o orientation posses a flexural strength of 387.725 N/mm2 impact strength of 87 KJ/m2 which was higher when compared with others. Orientation helps to boost up the mechanical properties of the composites [11]. K.Vasantha Kumar, Dr.P.Ram Reddy, Dr.D.V.Ravi Shankar investigated about Effect of Angle Ply Orientation On Tensile Properties Of Bi Directional Woven Fabric Glass Epoxy Composite Laminate, they concluded that glass/Epoxy with 0^{o}fiber orientation Yields' high strength when compare to other degree of orientations for the same load, size & shape In addition glass/epoxy with 0^{o}orientation have higher strength, [12]. R. Sino,T.N. Baranger,E. Chatelet,G. Jacquet investigated about Dynamic analysis of a rotating composite shaft they concluded that closer the fiber is oriented to 90^o,the greater the internal damping and the sooner instability may appear. Equivalent rigidity decreases as a function of ply angle, whereas, the damped equivalent rigidity increases [13].

2. COMPOSITE MATERIAL

A material composed of 2 or more constituents is called composite material. Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and or not soluble in each other. The main difference between composite and an alloy are constituent materials which are insoluble in each other and the individual constituents retain those properties in the case of composites.

CLASSIFICATION OF COMPOSITES

- Polymer matrix composites
- Metal matrix composites
- Ceramic Matrix

3. METHODOLOGY:

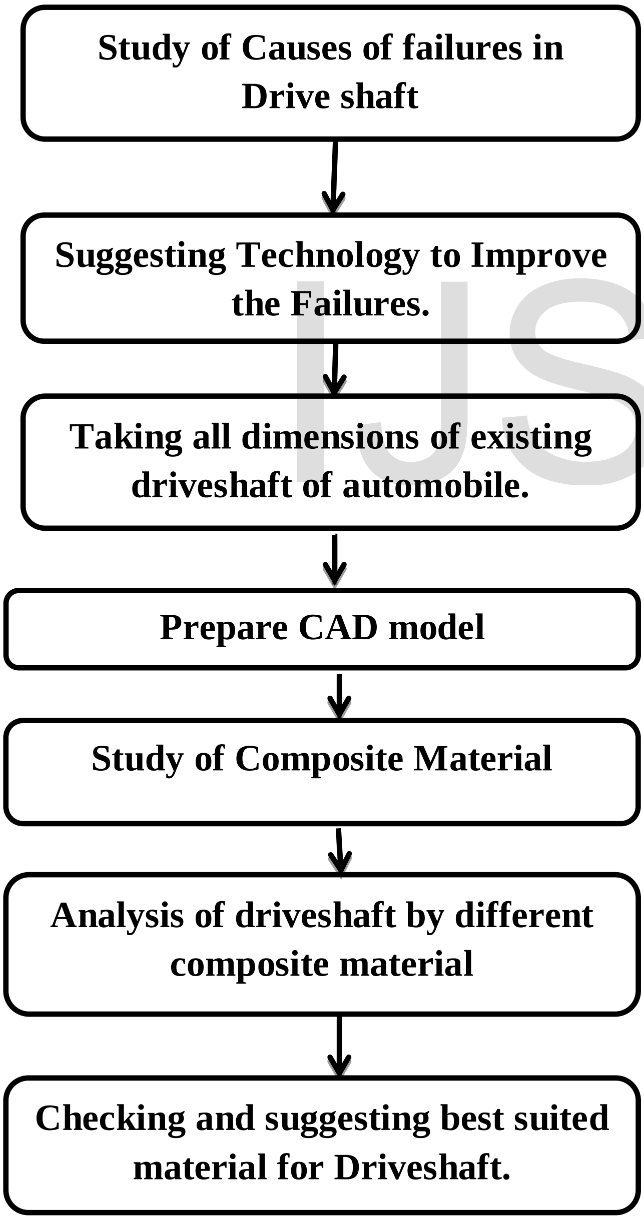

Fig:3 Methodology

4. MODELING IN CATIAV5

CATIA V5 supports multiple stages of product development, including conceptualization, design (CAD), engineering (CAE) and manufacturing (CAM). CATIA facilitates collaborative engineering across disciplines around its 3DEXPERIENCE platform, including surfacing & shape design, electrical fluid & electronics systems design, mechanical engineering and systems engineering.(Fig:3&4)

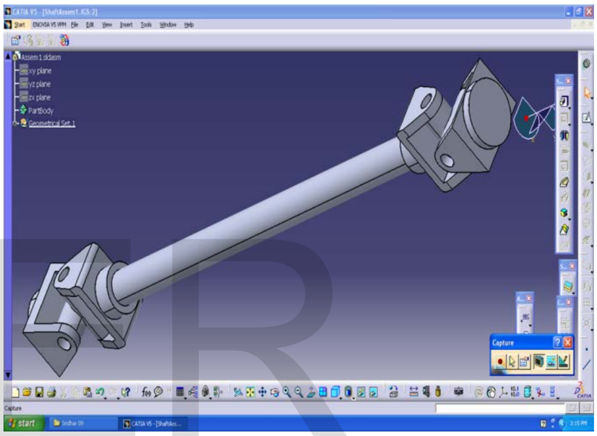

Fig:4 Catia modelling of Drive Shaft

5. DESIGN PARAMETERS

Parameter of shaft	Symbol	Value	Unit
Outer Diameter	d_o	90	mm
Inner Diameter	d_i	83.36	mm
Length of the shaft	L	1250	mm
Thickness of the shaft	T	3.32	mm

Table:1 Tabulation of Design Parameters

6. SELECTION OF REINFORCEMENT FIBER

Fibers are available with widely differing properties. Review of the design and performance requirements usually dictate the fiber/fibers to be used.

S.No	Property	Units	Steel	E-Glass Epoxy	HS – Glass Epoxy	HM Carbon Epoxy
1	E11	Gpa	200	50.0	134.0	190.0
2	G12	Gpa	2.2	5.6	5.8	4.2
3	Prx (γ)	-	0.3	0.3	0.3	0.3
4	$S^t_1 = S^c_1$	MPa	250	800.0	880.0	870.0
5	$S^t_2 = S^c_2$	MPa		40.0	60.0	54.0
6	S_{12}	MPa		72.0	97.0	30.0
7	ρ	Kg/m^3	$7.85E^6$	2000.0	1600.0	1600.0

Table:2 Material Selection

7. RESULT AND DISCUSSION

Finite element analysis is a computer based analysis technique for calculating the strength and behavior of structures. In the FEM the structure is represented as finite elements. These elements are joined at particular points which are called as nodes. The FEA is used to calculate the deflection, stresses, strains temperature, buckling behavior of the member. In our project FEA is carried out by using the ANSYS 12.0. Initially we don't know the displacement and other quantities like strains, stresses which are then calculated from nodal displacement

8. MODAL ANALYSIS

When an elastic system free from external forces can disturbed from its equilibrium position and vibrates under the influence of inherent forces and is said to be in the state of free vibration. It will vibrate at its natural frequency and its amplitude will gradually become smaller with time due to energy being dissipated by motion.[8] The main parameters of interest in free vibration are natural frequency and the amplitude. The natural frequencies and the mode shapes are important parameters in the design of a structure for dynamic loading conditions. Modal analysis is used to determine the vibration characteristics such as natural frequencies and mode shapes of a structure or a machine component while it is being designed. Modal analysis is used to determine the natural frequencies and mode shapes of a structure or a machine component. Rotational speed is limited by lateral stability considerations fig (5 to8).

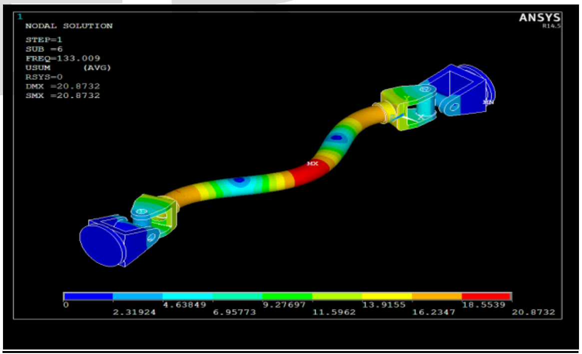

Fig:5 STEEL

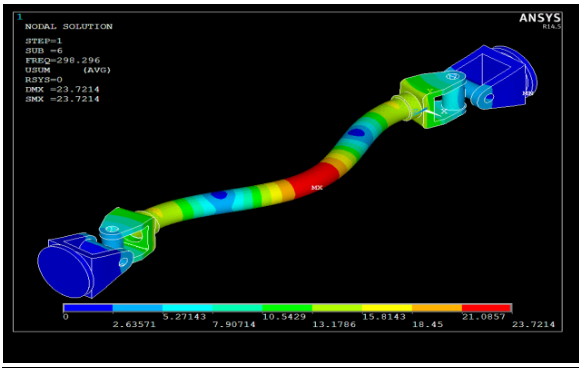

Fig:6 E – GLASS EPOXY

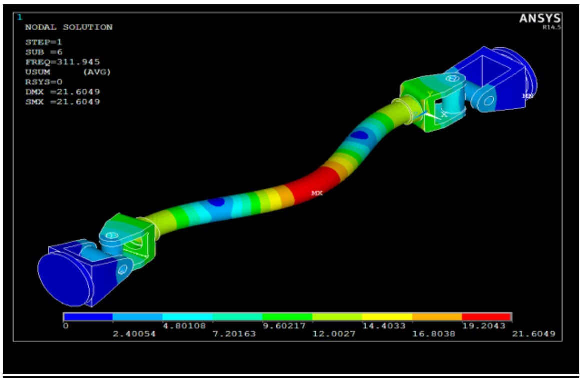

Fig:7 HM CARBON EPOXY

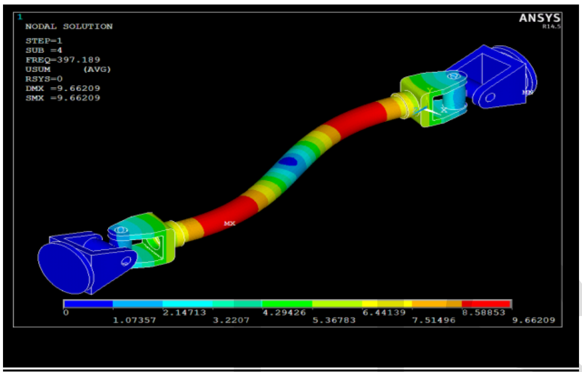

Fig:8 HS CARBON EPOXY

9. STRESS ANALYSIS

A static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects. A static analysis can however include steady inertia loads such as gravity, spinning and time varying loads.[9] In static analysis loading and response conditions are assumed, that is the loads and the structure responses are assumed to vary slowly with respect to time. If the stress values obtained in this analysis crosses the allowable values it will result in the failure of the structure fig (9to12).

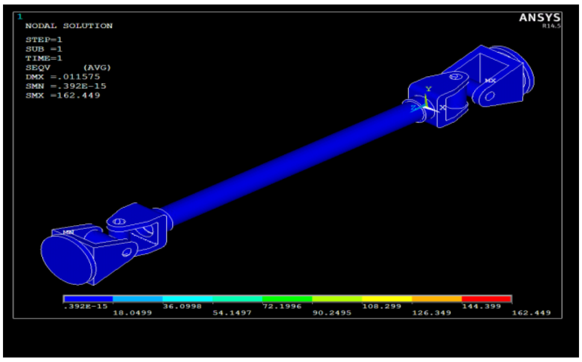

Fig:9 STEEL

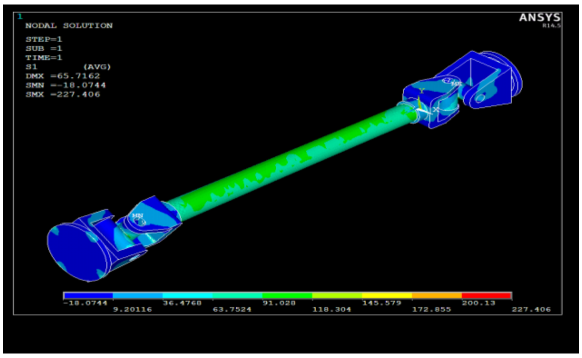

Fig:10 E – GLASS EPOXY

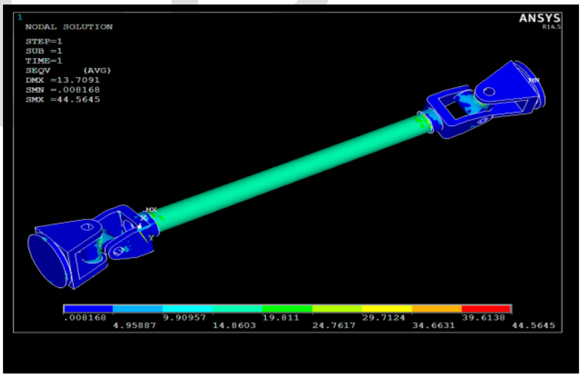

Fig: 11HM CARBON EPOXY

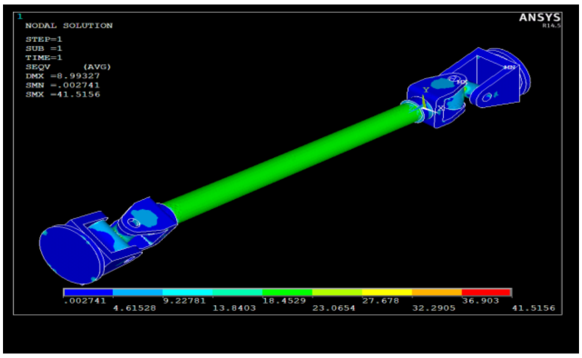

Fig: 12 HS CARBON EPOXY

10. COMPARISON OF FINAL RESULT

Parameter	Steel	E-Glass / Epoxy	HS Carbon/Epoxy	HM Carbon/Epoxy
Deformation		65.716	13.709	8.993
Stress		227.106	44.564	41.515
Weight (kg)	8.63	5.26	4.36	4.23
Weigh reduce in %	---	39	49.5	51
Damped Frequency in Hz	133.009	298.296	311.945	397.189

Table:3 Final Result Comparison

When compare to Steel, E-Glass/ Epoxy, High Strength Carbon/Epoxy materials for Automobile drive shaft High Modulus Carbon/Epoxy has the high strength, less weight hence it is used as the optimized material for automobile drive shaft (Table 3).

11. CONCLUSION

The replacement of conventional drive shaft results in reduction in weight of automobile. The finite element analysis is used in this work to predict the deformation of shaft. The deflection of steel, Glass Epoxy / HS Carbon and HM Carbon / Epoxy shafts was 298.296, 311.945 and 397.189 mm respectively. Natural frequency using Bernoulli – Euler and Timoshenko beam theories was compared. The frequency calculated by Bernoulli – Euler theory is high because it neglects the effect of rotary inertia & transverse shear. Hence the single piece High Strength Carbon / Epoxy composite drive shaft has been proposed to design to replace the two piece conventional steel drive shaft of an automobile. The FEA analysis is done to validate the analytical calculations of the work.

The results of the work are encouraging and suggesting to replacement of conventional drive by composite has an added advantage. The next phase of work consists of Optimization of shaft for the objective function as weight and fundamental natural frequency.

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