Design and Analysis of Drive Shaft of an Automobile

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Abstract — *This paper presents the characteristic details of propeller shaft to substitute its material with composite material and suitability of material is analysed by evaluating and comparing stress distribution & deformation with in the shaft to replace the steel drive shaft with a piece of E-glass/ epoxy and E-carbon/epoxy with the help of material properties. The 3D modelling and assembly of Cardan shaft was done using CATIA V5 R21 software. Analysis is performed by using commercial FEA software ANSYS by considering static structural, Rigid dynamics and modal analysis to estimate deformation, stress under given loads and frequencies. The main objective of this paper is deduction of weight of an automobile transmission.*

Keywords — *Cardan shaft, transmission, differential, rigid dynamics, frequencies.*

I. INTRODUCTION

A drive shaft or Cardan shaft is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them. As torque carriers, drive shafts are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia. An automobile may use a longitudinal shaft to deliver power from an engine/transmission to the other end of the vehicle before it goes to the wheels. A pair of short drive shafts is commonly used to send power from a central differential, transmission, or transaxle to the wheels.

Drive shaft for Research and Development of the automotive industry also uses drive shafts at testing plants. At an engine test stand a drive shaft is used to transfer a certain speed / torque from the internal combustion engine to a dynamometer. A "shaft guard" is used at a shaft connection to protect against contact with the drive shaft and for detection of a shaft failure. At a transmission test stand a drive shaft connects the prime mover with the transmission. Composite materials typically have a lower modulus of elasticity. As a result, when torque peaks occur in the driveline, the driveshaft can act as a shock absorber and decrease stress on part of the drive train extending life. Many researchers have been investigated about hybrid drive shafts and joining methods of the hybrid shafts to the yokes of universal joints. But this study provides the analysis of the design in many aspects. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and higher specific strength of composite materials. Composite materials can be tailored to efficiently meet the design requirements of strength, stiffness and composite drive shafts weight less than steel or aluminium of similar strength

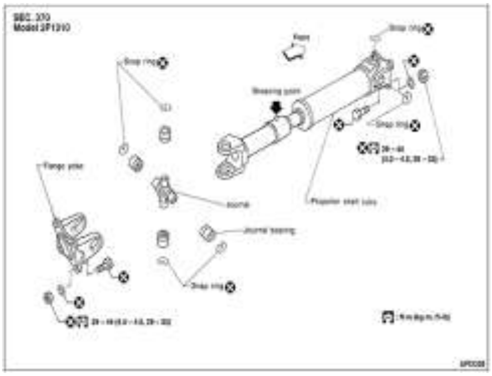


Figure 1 details of drive shaft.

II. OBJECTIVE

The power train of vehicle have several parts in which propeller shaft is heart of transmission which encounter unfortunate obstacles called failures. This damage is due to several faults, the main reason is material and its manufacturing and maintenance. Early automobiles often used chain drive or belt drive mechanisms rather than a drive shaft. Some used electrical generators and motors to transmit power to the wheels. Hence now it is challenging to design the drive shaft for an automobile with objective weight deduction by no increase in cost to increase transmission of power produced by engine. Hence material selection is one of the important issues for transmitting variable torque to wheels with different road conditions. In this comparative has been made in analysis of shafts with material differ which leads to weight deduction by analysing in static structural and modal analysis to calculate vibrations in shaft.

III. DESCRIPTION OF THE PROBLEM

Stainless steel was mainly used because of its high strength. But this stainless steel shaft has less specific strength and less specific modulus. Stainless steel has less damping capacity. Because of its higher density of molecules of stainless steel, its weight is very high. Because of increase in weight fuel consumption will in increase, the effect of inertia will be more and increase in weight. The steel propeller shaft is replacing with the composite materials, which are very less weight when compared to that of stainless steel. The cost of composite materials is less when compared to that of stainless steel. The E-Glass/Epoxy and Carbon/Epoxy materials are selected for composite drive shaft. Since, composites are highly orthotropic and their fractures were not fully studied.

TABLE I

S.no	Physical Property		
	Property	**Notation**	**Value**
1.	Ultimate Torque	T	1250 N-mm
2.	Maximum Speed of the Shaft	N	2500 rpm
3.	Maximum diameter of the Shaft	D	□ 100 mm
4.	Length of the Drive	L	1650 mm
5.	Rotational Velocity	V	260 rad/sec
6.	Maximum Range of Frequency	F	2500 hz

- Rotational velocity = $2\pi N/60$ rad/sec
  = (2 X 3.14 X 2500)/60
  = 260 rad/sec
- Length of shaft – 825 mm
- Minimum diameter of the shaft - □ 70 mm
- Total torque to be transmitted (Tt) = Ip x f x Y
  =1448 N-mm

Where,
Ip-polar moment of inertia-162
F-stress in (pa) - 2.75 N
Y-distance of the external fiber to neutral fiber- 3.25 mm

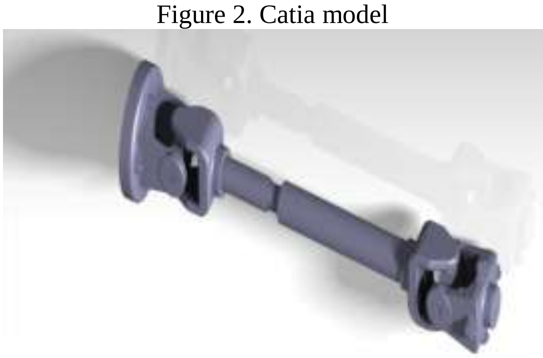
TABLE III

Mechanical property	Materials of cardan shaft and their Mechanical properties		
	Steel	**Glass/ Epoxy**	**Carbon /Epoxy**
Young's Modulus	210 Gpa	39 Gpa	177 Gpa
Poisson's Ratio XY	0.3	0.3	0.3
YZ		0.3	0.263
ZX		0.3	0.3
Density (kg/m3)	7850	2000	1600 kg/m3
Shear Modulus	80 Gpa	3.8 Gpa	7.8 Gpa
Tensile Ultimate strength	4.6E+08 pa	4.0E+08 pa	4.4E+08 pa

A. DESIGN TOOL (CATIA V5 R21)

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing. It provides tools to complete product definition, including functional tolerances as well as kinematics definition. CATIA provides a wide range of applications for tooling design, for both generic tooling and mould & die. CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. CATIA provides a wide range of applications for tooling design, for both generic tooling and mould & die.

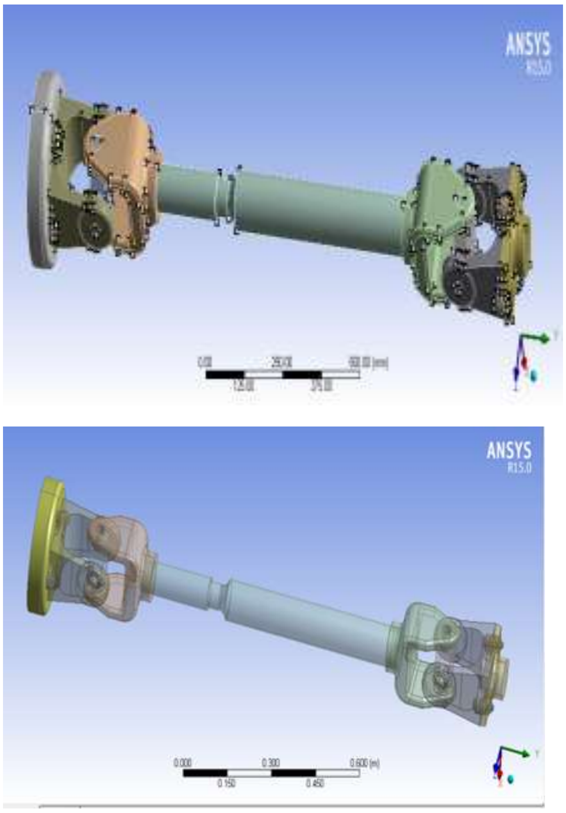
Figure 2. Catia model



B. ANALYSIS (ANSYS WORKBENCH 15.0)

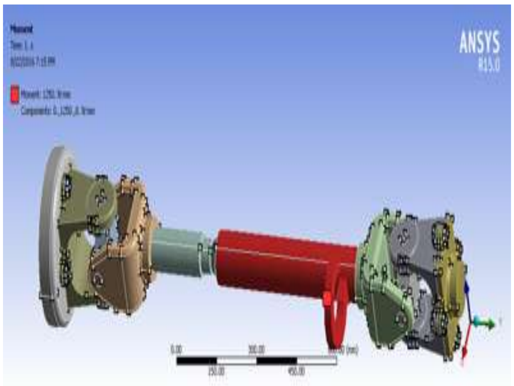
ANSYS 15.0 brings together new capabilities and enhancements that offer a more comprehensive approach to guide and optimize complete product designs. As products trend toward greater complexity — with advanced functionality and features, novel materials, embedded electronics and their resulting thermal issues, and control software for smart.

Figure 3.Generated model in Ansys.



IV. ANALYSIS OF DRIVE SHAFT

Assumptions the shaft rotates at a constant speed about its longitudinal axis. The shaft has a uniform, circular cross section. The shaft is perfectly balanced. Hexa Mesh is made for better result and 20000 elements made with fine mesh size. The regular FEA procedure is followed and obtained results were plotted and compared.



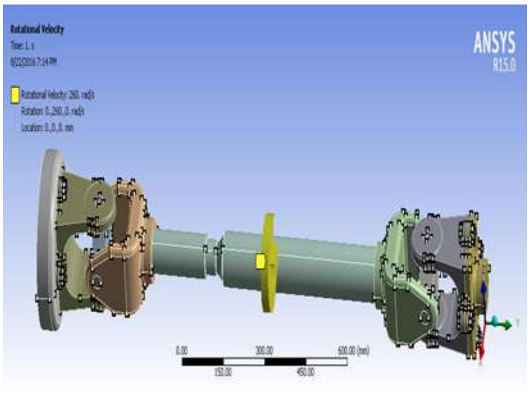


Figure 4.Moment and Rotational velocity in static structural analysis.

1. *STATIC STRUCTURAL*

The figures shown below represent deformation, stress and strain of different materials.

Structural steel

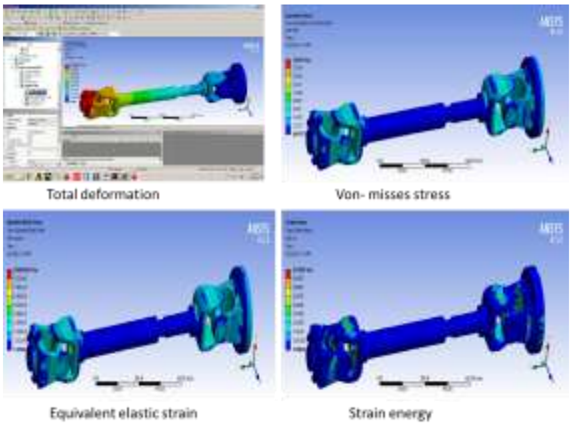


Figure.5

E-carbon

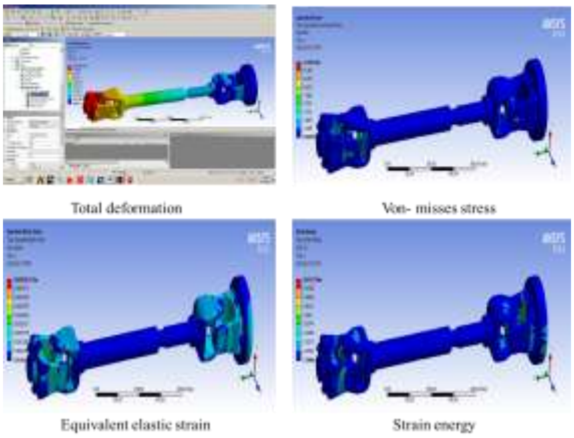


Figure.6

E-glass

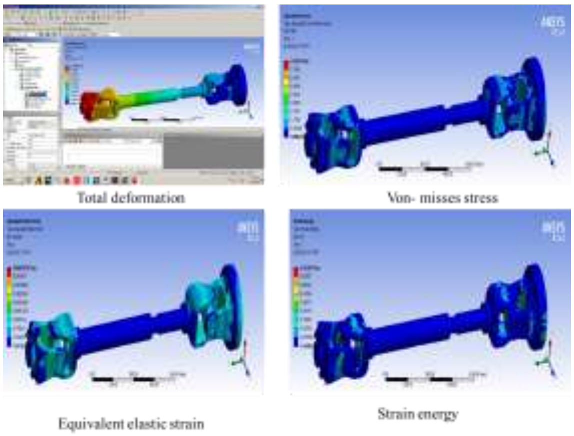
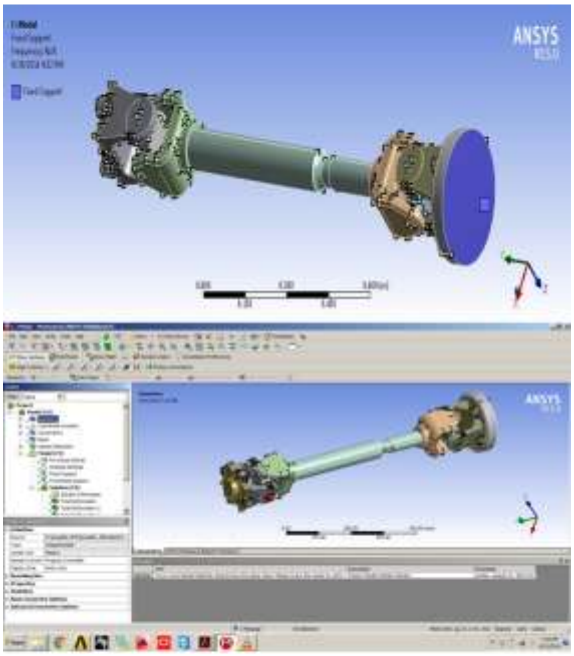


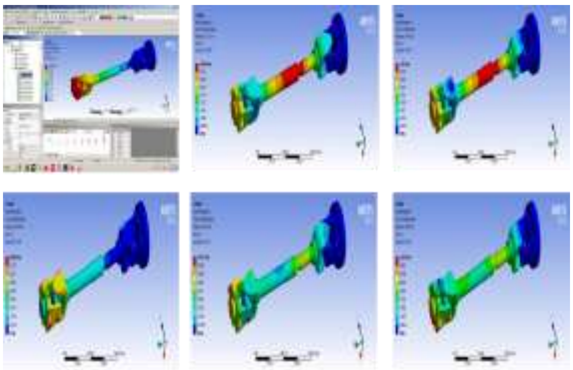
Figure.7

2. MODEL ANALYSIS



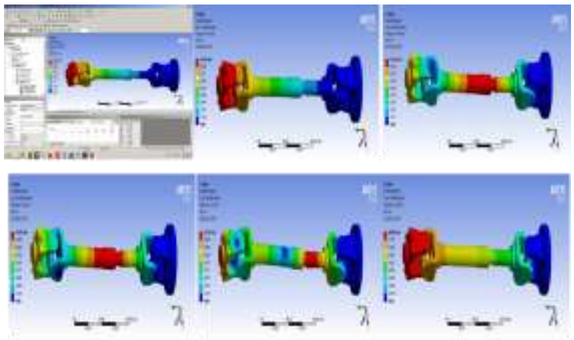
Fixed support and friction less support

Figure.8



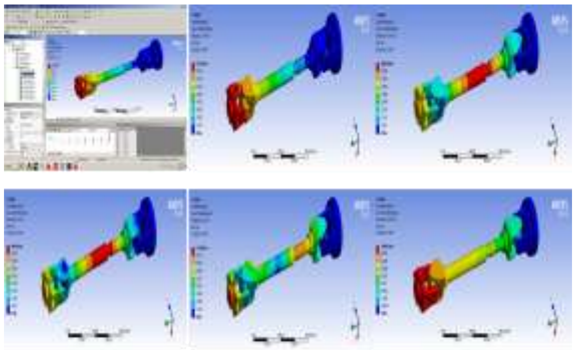
Mode shape results of structural steel

Figure.9



Mode shape results of E- carbon

Figure.10



Mode shape results of E-glass

Figure.11

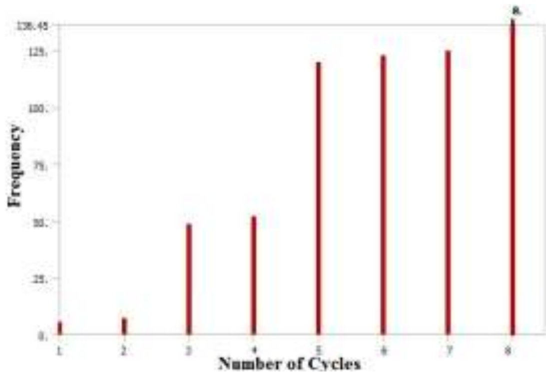


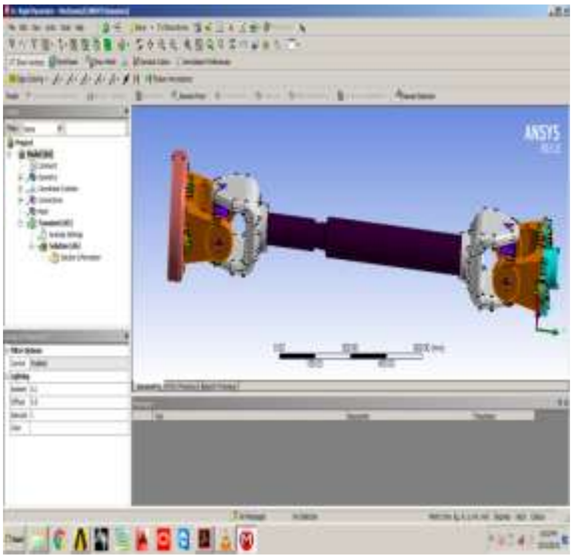
Figure.12

The above graph and figures shows the maximum frequency at each cycle. The maximum range of frequency is chosen as 2500HZ. The maximum deformation is observed at fifth cycle for all materials while analysis, hence the part is under safe condition to given frequency also. To avoid misshaping we can replace sharp corners with fillet edges to minimize the stress concentration factor.

3. *RIGID DYNAMIC ANALYSIS*

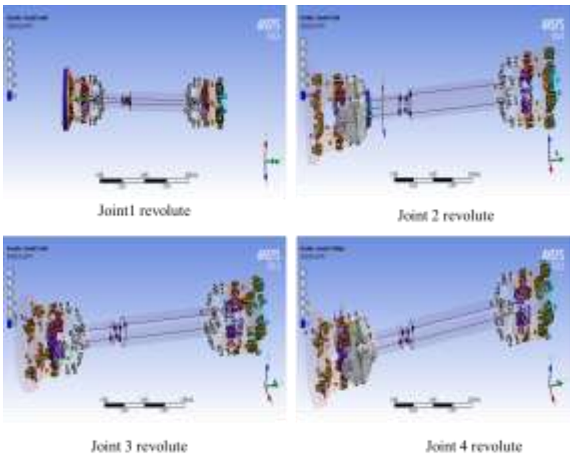
Rigid dynamics simulation can demonstrate how quickly an assembly's parts are moving, how fast the parts are accelerating or decelerating, and what the forces are at the joints between the parts at any time during the dynamic transient. The total solution time for many rigid dynamics simulations is often measured in seconds, because the number of degrees of freedom is low and all parts are assumed to be infinitely stiff. This fast solves time makes rigid dynamics extremely attractive to those with looming deadlines.

The most basic and most widely used method of combining the benefits of rigid dynamics with those gained by using flexible system modelling is to transfer loads from a rigid dynamics run and use those loads on a structurally static system.



Generated colour model in RD modeller

Figure.13



Fully constrained with DOF

Figure.14

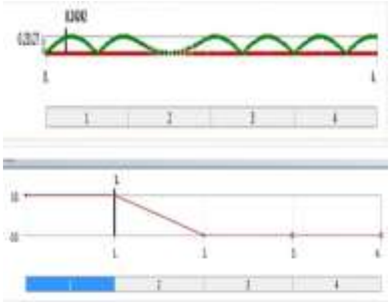


Figure.15 graphs of analysis

V. CONCLUSIONS

	Results		
	Steel	**E-glass**	**E-carbon**
Deformation(mm)	0.05013	0.1639	0.15262
Stress (mpa)	19.835	8.228	12.928
Strain	0.70904	0.719	0.617

1. Due to the Weight reduction and stress, stiffness criteria, drive shaft is proposed to be replaced with E- Glass Epoxy composite drive shaft as per plotted results above.
2. Taking into considerations the weight saving, deformation, shear stress induced and frequencies it is evident that E-Glass/Epoxy composite has the most encouraging properties to act as replacement for steel out of the considered three materials.
3. Hence by using different analysis like static structural, modal analysis and rigid dynamics we had been checked the various conditions that may drive shaft undergone and encountered different problems facing to replace the steel with composites.
4. The modal analysis shows even if composite material having half of natural frequency of steel it is replaceable in natural frequency point of view carbon epoxy is best suitable material for drive shaft.
5. The drive shaft of the dimensions, which were used then used for the material properties of composites were used the stability of drive shaft is ensured by limiting the include values within the permissible range in Ansys workbench 15.0.
6. By considering rigid dynamic analysis, the E-glass epoxy has more similar issues by comparing with rest of composites.

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