Design, Analysis and experimental validation ofcomposite propeller shaft of three wheeler

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Abstract — *Nowadays, a composite material is used as replacement of the conventional materials in Automobile industries because of high strength to light weight properties, which reduces the overall vehicle weight without compromising the strength and reliability. Composite materials with higher specific stiffness, low weight, high damping capacity have greater torque capacity than conventional drive shaft. The advanced composite materials such as carbon and glass with epoxy resin are widely used because of their high specific strength and high specific modulus. The aim of this work is to replace the conventional steel driveshaft of automobiles with an appropriate composite driveshaft. Study also includes the preparation of composite shaft in single piece for overall weight reduction, whereas the conventional drive shafts are made in two pieces for reducing the bending natural frequency. In this approach, optimum designed drive shaft finite element model will be prepared in finite element commercial software ANSYS. The static, free vibration and Tensional buckling analysis will be done which are very much essential for rotating elements like drive shafts. Experiment also conducted on instrument to measure the mechanical properties of composite shaft.*

Keywords — *Drive shaft, Carbon composite, Hybrid composite, ANSYS analysis.*

I. INTRODUCTION

Automobile industries are exploring composite materials usage by replacing the conventional one because of light weight properties which reduces the vehicle weight without compromising the quality and reliability [1] [2]. The advanced composite materials such as carbon, glass, graphite and Kevlar fibers with suitable resins are widely used because of their high strength to weight ratio and high specific modulus (modulus/density). Advanced composite materials seem ideally suited for long, power driver shaft (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. The drive shafts are used in automotive, aircraft and aerospace applications. 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.

The Renault Espace Quadra, launched in 1988, was the pioneering application for composite prop-shafts in production vehicles. A one-piece composite shaft was specified, in place of the alternative two-piece steel shaft solution. The majority of Renault Espace production was front wheel drive vehicles; use of a composite shaft for the four wheel drive versions reduced the engineering modifications required for the floorpan. The floor was in any case sensitive to noise and vibration inputs, which were improved by the absence of a prop-shaft centre support bearing. The composite propeller shaft system weighed 5 kg, compared to 10 kg for the two-piece steel alternative. The vehicle remained in production until 1996, at which time the Quadra version was deleted from the product range. This was a consequence of other engineering changes which led to the orientation of the engine becoming transverse instead of longitudinal, and four wheel drive was then no longer practical [3]. A CV joint at each end of the drive shaft meets the angle requirement and a plunge CV joint accommodates the length change. Rear-wheel drive vehicles having independent rear suspension need a drive shaft to connect the road wheel to the fixed final drive assembly [4].

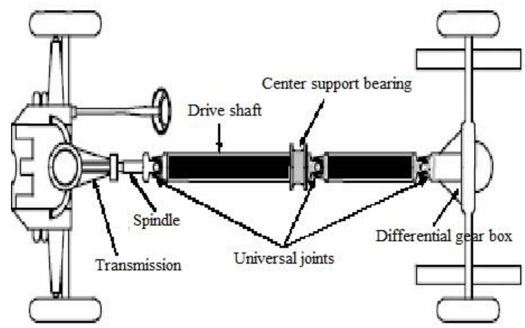

FIGURE 1 CONVENTIONAL TWO-PIECE DRIVE SHAFT ARRANGEMENTS [4]

II. DRIVE SHAFT

In British English, the term "drive shaft" is restricted to a transverse shaft that transmits power to the wheels, especially the front wheels. A drive shaft connecting the gearbox to a rear differential is called a propeller shaft, or prop-shaft. A prop-shaft assembly consists of a propeller shaft, a slip joint and one or more universal joints. Where the engine and axles are separated from each other, as on four-wheel drive and rear-wheel drive vehicles, it is the propeller shaft that serves to transmit the drive force generated by the engine to the axles.

These evolved from the front-engine rear-wheel drive layout. A new form of transmission called the transfer case was placed between transmission and final drives in both axles. This split the drive to the two axles and may also have included reduction gears, a dog clutch or differential. At least two drive shafts were used, one from the transfer case to each axle. In some larger vehicles, the transfer box was centrally mounted and was itself driven by a short drive shaft. In vehicles the size of a Land Rover, the drive shaft to the front axle is noticeably shorter and more steeply articulated than the rear shaft, making it a more difficult engineering problem to build a reliable drive shaft, and which may involve a more sophisticated form of universal joint.

III. LITERATURE REVIEW

Fiber reinforced plastics (FRP) have been engineered into materials that meet the stringent requirements of today's technology. High modulus, high strength to weight ratio have made composite materials particularly amenable to the requirement of the aerospace, automobile and machine tool industries. Composite materials have excellent properties like high specific strength and stiffness, high damping, low thermal expansion and good dimension stability [15]. Conventional materials are replaced by composite materials in so many fields due to their lightweight and easy processing. Nowadays hybrid composite drive shafts are also used in replacement of the steel and aluminum for the preparation of these composites drive shafts [17]. Synthetic fibers mainly carbon, glass, Kevlar have satisfactory strength properties coupled with relatively low cost, recyclability and biodegradability and are being used in automotive industries, construction as well as in packaging industries with few drawbacks. The low density of fibers allows fabrication of composites that gives good mechanical properties with a low specific mass. The increased interest in the use of fiber among researchers and technologist's has been well known.

H. Bankar et al. [18] carried out analysis on Steel, Boron/epoxy composite, Kevlar/epoxy composite, Aluminium-Glass/epoxy hybrid, Carbon-Glass/epoxy hybrid materials by varying three different ply orientations. Suitable stacking of layers leads to reduction in weight and stresses in composite shaft; most appropriate ply orientation is selected to reduce the maximum weight of the shaft. The stress distribution and the maximum deformation are the functions of the stacking of materials in the shafts.

B. Gireesh et al. [19] modeled the composite drive shaft by using E- glass/epoxy resin and carried out the analysis using ANSYS. A result for maximum deformation, maximum and minimum stresses and also by varying the fiber angle orientation sequence to 45-45-45-45 composite drive shaft is compared with that of steel. About 72% of weight savings and orientation of fibers plays a vital role in the static analysis of composite drive shaft and offers lower weight, higher strength; progressive failure mechanism (offers warning before failure), lower power consumption.

A. Gebresilassie [20] carried out theoretical and numerical analysis on three composite shafts made up of E-Glass/epoxy resin by varying the torque and the critical speed for different lengths and diameters. Results show that there is a linear relationship between the deflection and torque, torque and stress, and torque and strain.

M.R. Khoshravan and A. Paykani [21] studied the design method and a vibration analysis of a carbon/epoxy composite drive shaft. Effects of different parameters such as critical speed, static torque, fiber orientation and adhesive joints were studied. The fibers orientation angle has a big effect on the natural frequency of the drive shaft. The fibers must be oriented at zero degree to increase the natural frequency by increasing the modulus of elasticity in the longitudinal direction of the shaft. A mass comparison between steel and composite drive shafts has been done. The substitution of composite shaft has resulted in considerable weight reduction about 72% compared to conventional steel shaft.

B. Bakir and H. Hashem [22] 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.

IV. DESIGN AND ANALYSIS OF DISK BRAKE ROTOR

Atulshakti three wheeler premium loading vehicle as collected from the brochure of the vehicle.The material properties of the steel shaft is given by the supplier.

Steel shaft is developed using Creo parametric 4.0 software using exiting dimension of Atulshakti three wheeler premium loading vehiclesteel drive shaft properties as given in table 1. Figure 2 and 3 shows the 3D model of drive shaft and meshed model of drive shaft respectively.

Table: 1 Physical properties of steel SM45C

Property	Sym bol	Value
Young's modulus of elasticity	E	207GPa
Yield strength	σ_y	370 MPa
Poisson's ratio	μ	0.30
Shear modulus	G	80 GPa
Density	ρ	7600 Kg/m^3
Elongation	%	9.50

The stuctural analysis has been done on ANSYS software by static structural module as depicted in figure 2. Materials properties of the steel has entered manually from table 1 as shown in figure 2.By using above design calculations the modelling of the steel shaft is done as below and its simple geometry is shown below. Model was imported in ANSYS as shown in figure 3. In software after entering the material properties geometry option was selected. For the analysis surface was supressed and only solid geometry is selected for further analysis.

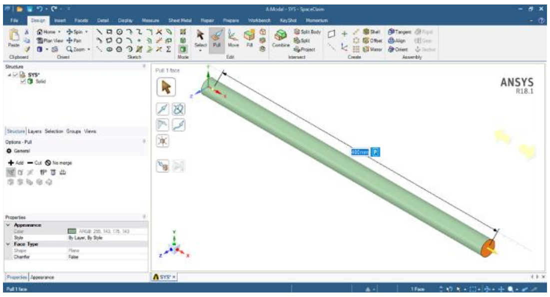

FIGURE 23D DRAWING IN ANSYS 18.1 SOFTWARE

Meshing is the process in which geometry is spatially discredited into elements and nodes. Results of the analysis is also depends upon the numbers of nodes and element selected in analysis. Mesh was refined to get good convergence of the load and displacement results. In present study following mesh type and size has been selected as demonstrated in figure 4.6. Smooth mesh type is selected to get good converge in result but larger mesh size also take more time to get solution.

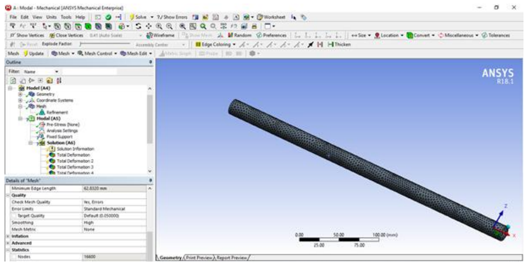

FIGURE 3Meshed drive shaft in ANSYS 18.1 software

Maximum load condition for drive shaft occurs during applying power transmission and acceleration the moving vehicle. The drive shaft is connected with differential gear box by bolts behaves as a fixed body offering zero displacement and withstand during braking operation. Hence significant boundary conditions that may apply for analysis are (i) gravity/weight acting downward (ii) rotation velocity/moment and (iii) fixed support. As in case of gear is applied by driver which transfer to torque from engine to shaft, drive shaft is considered as fixed at gear side by bolt is considered as fixed, which is having zero displacement in all the direction and braking torque is applied at both the side of shaft as shown in figure 4.

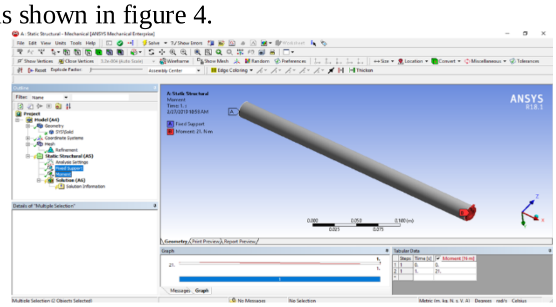

Figure 4 Boundary and loading condition in ANSYS 18.1

V. Results and discussion

In the present FEA study total deformation, equivalent stress, equivalent strain is considered for evaluating the results. The total deformation of the grey cast iron rotor of is calculated and the values obtained are the maximum deformation is 5.373 e-5 m and the minimum deformation is 0 as shown in figure 5.

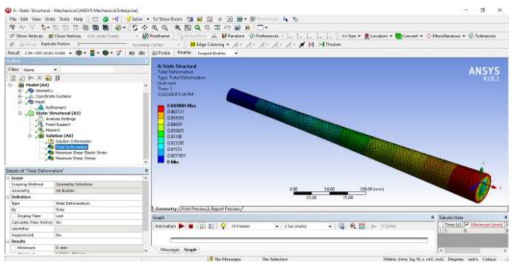

Figure 5 Total deformation of drive shaft

The equivalent elastic strain of the grey cast iron rotor is calculated and the values obtained are the maximum strain is 0.0001739 and the minimum deformation is 9.439e-7 as depicted in figure 6.

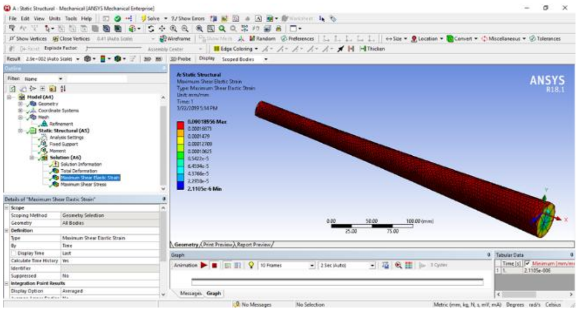

Figure 6 Equivalent elastic strain of drive shaft

The equivalent elastic stress of the grey cast iron rotor is calculated and the values obtained are the maximum stress is 110.52MPa and the minimum stress is 13.82MPa as shown in figure 7.

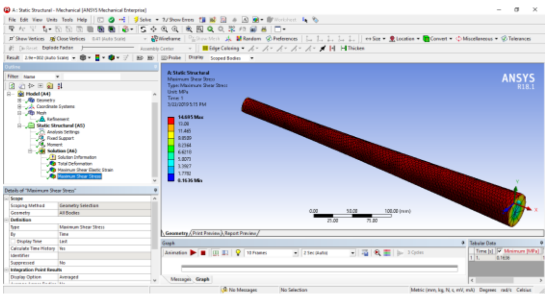

Figure 7 Equivalent elastic stress ofdrive shaft

A. Analysis of carbon composite shaft

The total deformation of the carbon composite drive shaft of outer diameter 28 mm and 20 mm inner diameter calculated and the values obtained are the maximum deformation is 0.2652 mm and the minimum deformation is 0 as shown in figure 8.

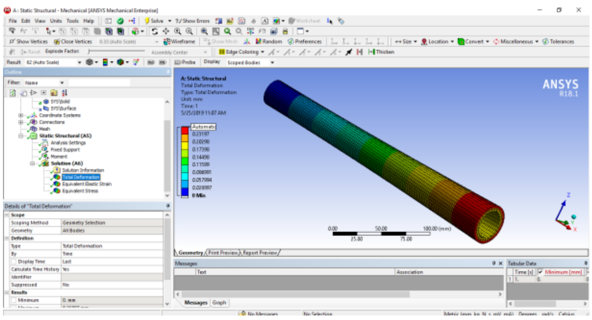

Figure 8 Total deformation of carbon composite shaft

The equivalent elastic strain of the steel drive shaft of diameter outer diameter 28 mm and 20 mm inner diameter calculated and the values obtained are the maximum strain is 0.00038574 and the minimum deformation is 0.00054927 as depicted in figure 9.

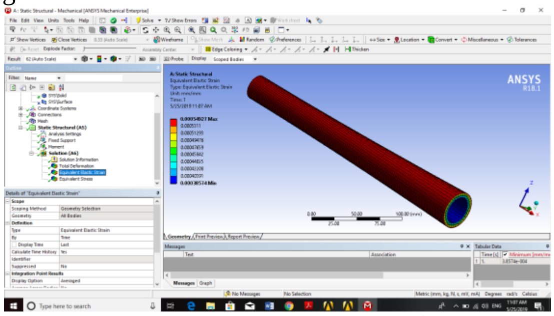

Figure 9 Equivalent elastic strain of carbon composite shaft

The equivalent elastic stress of the steel drive shaft of diameter outer diameter 28 mm and 20 mm inner diameter is calculated and the values obtained are the maximum stress is 11.52 MPa and the minimum stress is 8.0923 MPa as shown in figure 10.

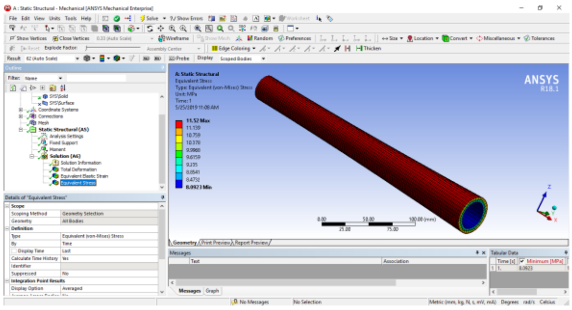

Figure 10 Equivalent elastic stress of carbon composite shaft

Parameters	Unit	Steel drive shaft	Manual Fabricated Carbon composite drive shaft
Deformation	m	5.373 e-5	2.6097e-4
Stress	MPa	13.849	11.52
Weight	Kg	0.764	0.144
% Reduce weight	-	-	81.15

VI. Conclusion

Composite analysis was done on ANSYS 18.1 for drive shaft having materials of steel.Steel has weight of 0.764 kg which may be replace by carbon copositematerial for disk brake having weight of 0.144 kg materials.

VII. References

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