International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.04, April 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Design and Comparative Analysis of Composite Shaft of Glass Fiber And Alloy Steel for Applications in Automotives

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ABSTRACT

Propeller shafts are an important part of the automobile transaxle drive train.Over the past years it is observed that the increasing use of composite materials in many fields of engineering and automotive applications. Composites are today extensively used to design the automobile components owing of their outstanding specific stiffness and strength properties. Composite shafts for automotive applications are among the most current areas of study and research. Weight reduction can be primarily achieved by the introduction of better material and design The conventional system uses metallic shaft in our case alloy steel (EN24), has inherent limitations like heavy weight, corrosion, flexibility problems, vibrations, bearing and manufacturing problems, which aggravates with increase in shaft diameter. Advanced composite materials offer the potential to improve propulsion shafting, by reducing weight, bearing loads, alignment problems, life- cycle cost by using strategic materials, by increasing allowable fatigue stress, flexibility, and vibration damping characteristics. This paper is related to Comparative study on Conventional alloy steel (EN 24) and glass Fiber Reinforced composite hollow shafts for automobiles applications .Unigraphix NX-8 has been used as the modelling software and the failure analysis has been carried out using maximum stress criteria using Ansys Workbench 16.0. The results of comparison have been displayed in terms of reduced weight and change in strength.

Keywords: *Alloy steel, Automobile, Glass fiber, Propeller shaft.*

1. INTRODUCTION

A driveshaft or driving shaft is a device that transfers power from the engine to the point where work is applied. In the case of automobiles, the drive shaft transfers engine torque to the drive axle, which connects the two wheels together on opposite sides and with which they turn. The driveshaft is also sometimes called propeller shaft.

Drive shafts are essentially carriers of torque. Before they became a vogue, older automobiles used chain drive and even generators to transmit power to the wheels. Drive shafts today, however, have U-joints, devices which help them to move and down during suspension. Some drive shafts also have another kind of joint, called slip joints, which allow them to adjust their lengths to the movement of the suspension.

Fig.1 Propeller Shaft

Drive shafts are essentially carriers of torque. Before they became a vogue, older automobiles used chain drive and even generators to transmit power to the wheels. Drive shafts today, however, have U-joints, devices which help them to move and down during suspension. Some drive shafts also have another kind of joint, called slip joints, which allow them to adjust their lengths to the movement of the suspension. The driveshaft uses flexible joints, called Universal joints (U-joints) or Constant Velocity joints (CV-joints) to couple the transmission/transaxle to the drive axle/drive wheels. The central hollow shaft is the element that is subjected to critical failure hence needs to be designed as it contributes significantly to the size and weight of the system

1.1 Methodology

1. Design of Alloy Steel drive shaft with available input parameter.
2. Select material for composite drive shaft
3. Analysis of both drive shaft using ansys.
4. Comparison of both drive shaft by theoretically and analytically.

2.DESIGN OF ALLOY STEEL SHAFT

Fig.2-Design Of Alloy Steel Shaft

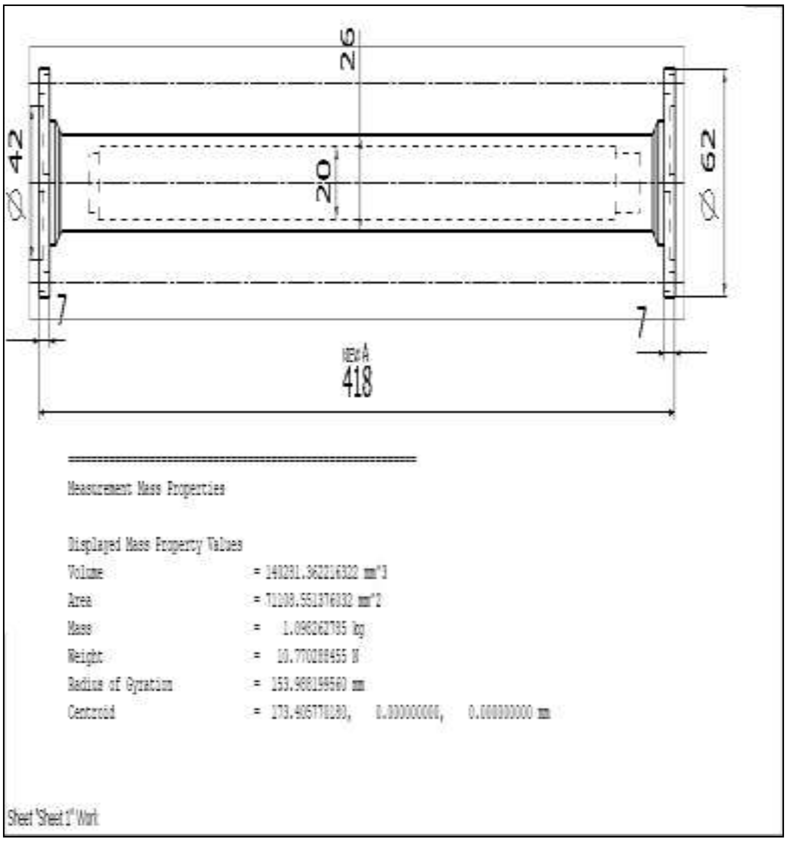

Table 1: Material Selection: -Ref: - PSG (1.10 & 1.12) + (1.17)

Designation	Ultimate Tensile Strength N/Mm^2	Yield Strength N/Mm^2

EN 24	800	680

$\Rightarrow$ fs_{max} = uts/fos = 800/2 = 400 N/mm^2

This is the allowable valve of shear stress that can be induced in the shaft material for safe operation.

Assuming 100 % efficiency of transmission

$\Rightarrow$ T design = 0.8 x (55/12) = 3.66 N-m

By considering the torsion Failure of The Hollow Portion of The Coupling Shaft,

$$Td = \Pi/16 \times fs_{act} \times (D4- d^4) /D$$

$$\Rightarrow fs_{act} = \frac{16 \times Td \times D}{\Pi \times (D^4- d^4)}$$

Outside diameter of boss = 26 mm

Inside diameter of drum boss =20 mm

$$= \frac{16 \times 3.66 \times 10^3 \times 26}{\Pi \times (26^4- 20^4)}$$

$\Rightarrow$ fs_{act} = 1.63N/mm^2

As $fs_{act} < fs_{all}$

Alloy steel shaft is safe under torsional load.

3. ANALYSIS OF ALLOY STEEL SHAFT

3.1 Geometry

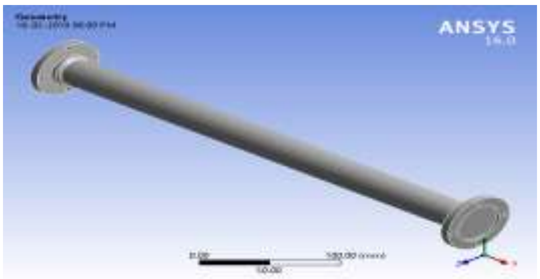

Fig.3-Geometry

The model was developed using UG-Nx software and the step file was used as input to the Ansys Workbench module

3.2 Meshing

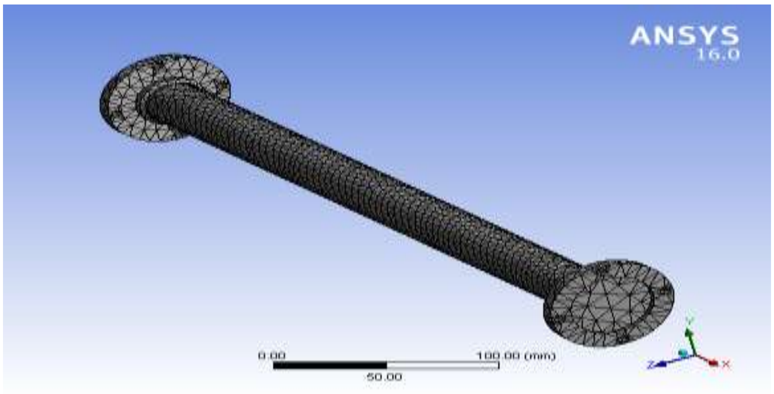

Fig.4- Meshing

Meshing parameters are as follows:

Statistics	
Nodes	19711
Elements	10079
Mesh Metric	None

3.3 Boundary Conditions

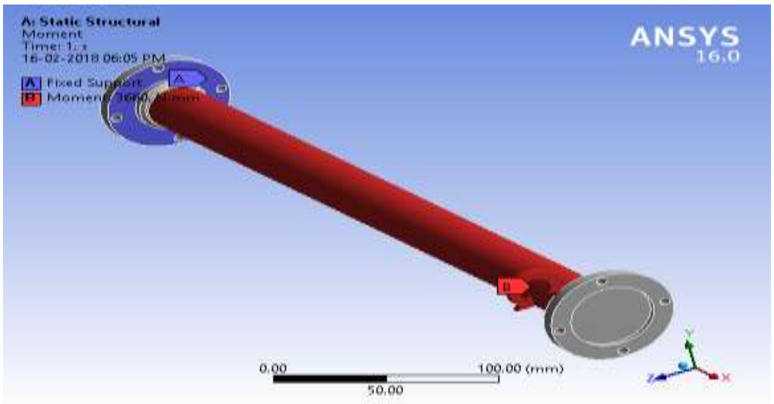

Fig.5- Boundry Conditions

The boundary conditions are that the shaft is fixed at the coupling end and the moment is applied about x-axis.

3.4 Result

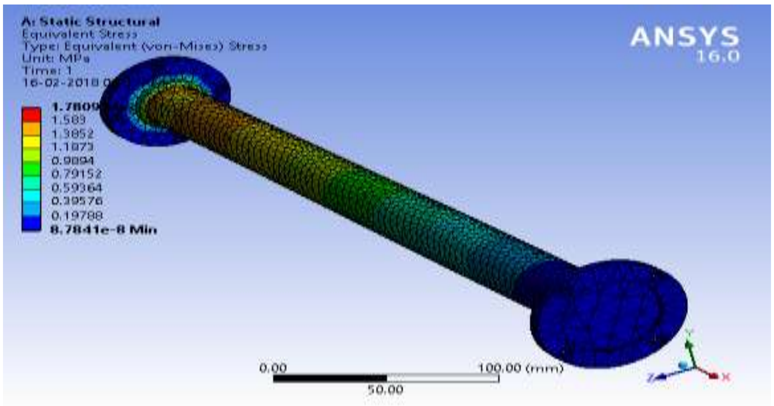

Fig.6 Result Of Maximum Stress

The maximum stress induced is 1.78 Mpa which is in close agreement with the theoretical value of 1.63 Mpa. Hence the design is validated.

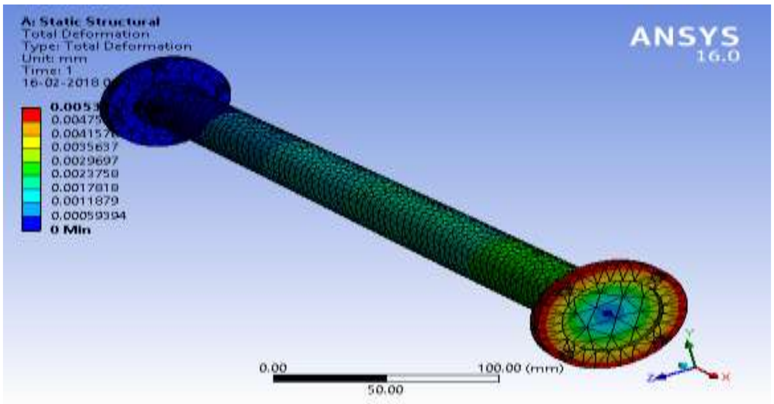

Fig.7 Result Of Deformation

The shaft shows very negligible deformation indicating that the shaft is safe under the given system of forces.

4. DESIGN OF COMPOSITE GLASS FIBER

International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.04, April 2018
www.ijarse.com
IJARSE
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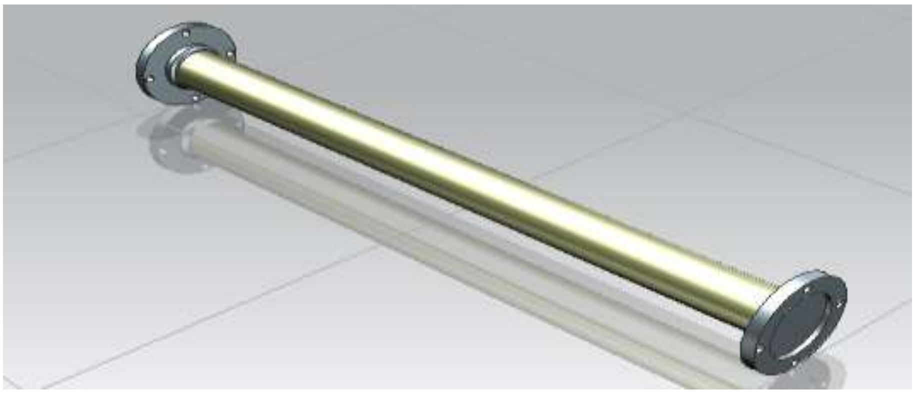
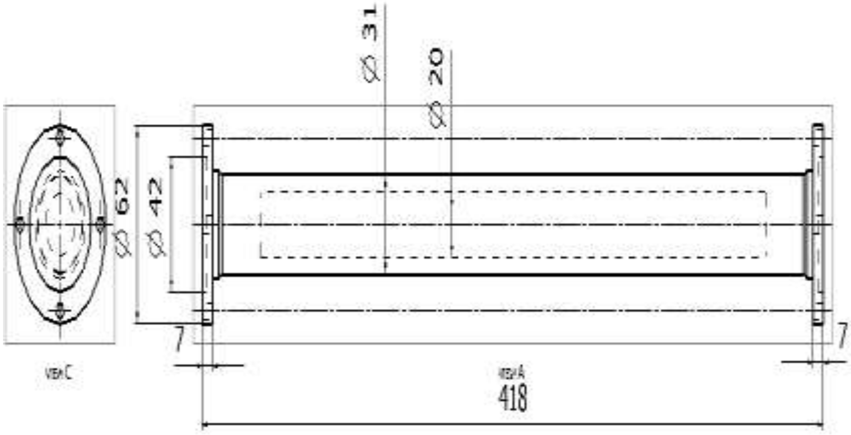


Fig.8 Design Of Composite Carbon Fiber Shaft



Measurement Mass Properties

Displayed Mass Property Values
Volume = 232304.356675363 mm^3
Area = 76040.865793305 mm^2
Mass = 0.736kg
Weight = 7.36N
Radius of Gyration = 140.742271337 mm
Centroid = 0.000000000, -0.000000000, 0.000000000 mm

Table 2. Material Selection : -Ref :- Psg (1.10 & 1.12)

Designation	Ultimate Tensile strength N/mm^2	Yield Strength N/mm^2

Glass fiber	1100	834

$\Rightarrow$ fs_{max} = uts/fos = 1100/2 = 550 N/mm^2

This is the allowable valve of shear stress that can be induced in the shaft material for safe operation.

Assuming 100 % efficiency of transmission

$\Rightarrow$ T design = 0.8 x (55/12)= 3.66 N-m

By Considering the Torsion Failure of the Hollow Portion of the Coupling Shaft,

$$Td = \Pi/16 \times fs_{act} \times (D^4 - d^4)/D$$

$$\Rightarrow fs_{act} = \frac{16 \times Td}{\Pi \times (D^4 - d^4)/D}$$

Outside diameter of boss = 31 mm

Inside diameter of drum boss =26 mm

$$= \frac{16 \times 3.66 \times 10^3 \times 31}{\Pi \times (31^4 - 26^4)}$$

$$\Rightarrow fs_{act} = 1.238 \text{ N/mm}^2$$

As $fs_{act} < fs_{all}$

Composite carbon fiber shaft is safe under torsional load.

5. ANALYSIS OF GLASS FIBER SHAFT

5.1 Geometry

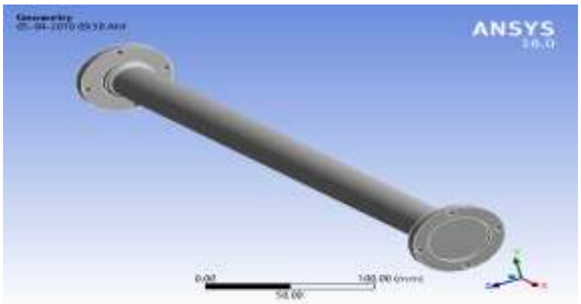


Fig.9 Geometry

The model was developed using UG-Nx software and the step file was used as input to the Ansys Workbench module.

5.2 MESHING

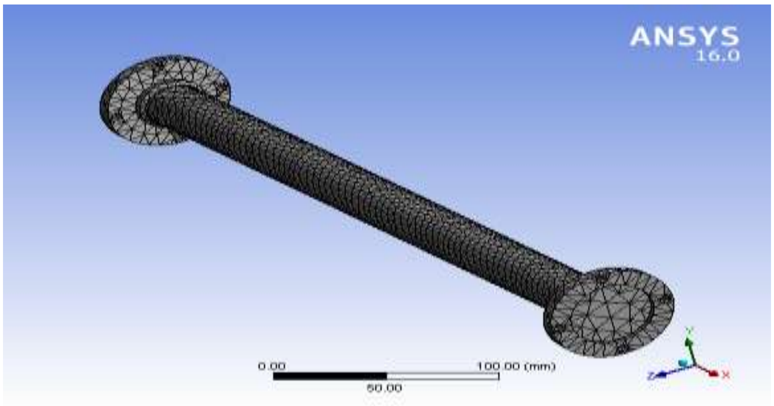


Fig.10 Meshing

Meshing parameters are as follows:

Statistics	
Nodes	19711
Elements	10079
Mesh Metric	None

5.3 BOUNDARY CONDITIONS

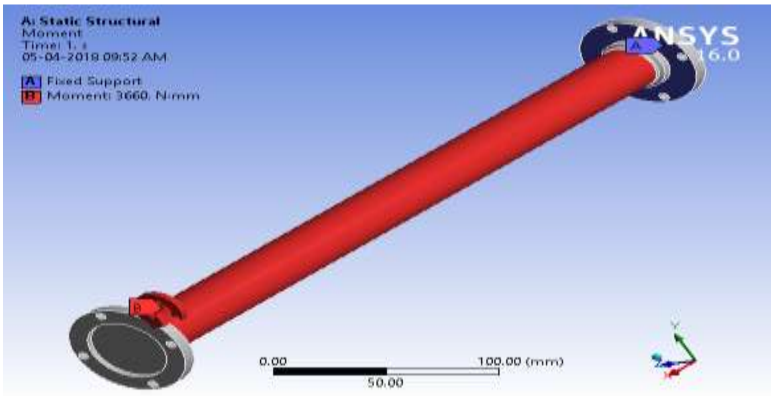


Fig.11 Boundry Conditions

5.4 RESULT

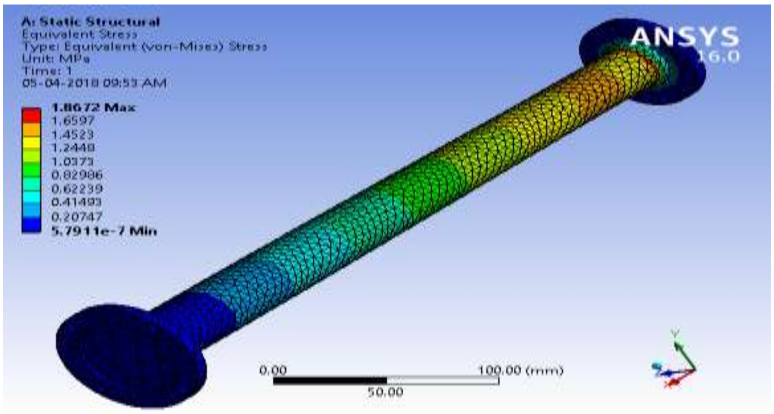


Fig.12 Result Of Maximum Stress

The maximum stress induced is 1.867Mpa which is in close agreement with the theoretical value of 1.238 Mpa. Hence the design is validated.

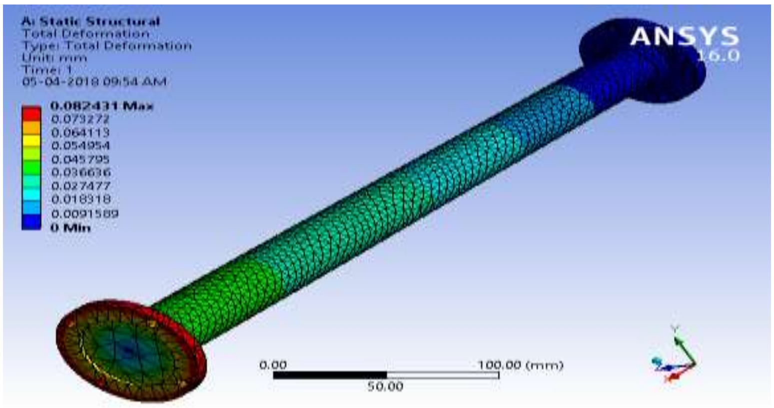


Fig.13 Result Of Deformation

The Composite shows a maximum deformation of 0.082 mm which is negligible hence it safe.

6. CONCLUSION

1. The alloy steel shaft with flanged end was developed and the net weight of the shaft was found to be 1.01 kg . Theoretical results and the analytical results of analysis are in close agreement , the maximum deformation is extremely negligible hence the steel shaft is safe, though a slight on heavier side.
2. The Glass fibre composite shaft with flanged end was designed and the net weight was found to be close to 0.736 kg which is low as compared to weight of the steel shaft & Theoretical results and the

analytical results of analysis are in close agreement , the maximum deformation is extremely negligible hence the composite carbon shaft is safe, and also lighter in weight.

3. The composite glass fibre is approximately 28 percent lower in weight than the steel shaft , though it shows slightly higher stress and more deformation than the steel shaft but well within the allowable limits , hence the carbon fibre design supercedes the steel shaft design . Hence the Glass fibre shaft is recommended over the steel shaft for applications in automotive industry.

ACKNOWLEDGMENT

It is a great pleasure for me to present this paper where guidance plays a very valuable key and provides strong platform for completion of the paper.

I would also like to express my sincere thanks to my internal guide Prof. Aher V.S.,Department of Mechanical Engineering, for his valuable encouragement and constant scrutiny without which I will not able to looked deeper into my work and realized both our shortcomings and our feats. This work would not have been possible without him. I am also grateful to other researchers and authors whose work provided a platform for this paper.

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