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# Design, Fabrication and Analysis of Composite Drive Shaft for Bicycle


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***Abstract:***

***A Drive Shaft, also known as propeller shaft is a mechanical part, that transmits the Torque generated by engine to propel the vehicle. In To-days competitive market, when concerned to the vehicles performance, in addition meeting the low cost requirements and customers satisfaction, the single piece drive shaft is the most important component to any power transmission application (bicycle or 3-wheeler).The physical appearance of the drive shaft resembles like a cylindrical structure of specified diameter. How-ever in this project, the composite drive shaft for a bi-cycle is considered. By replacing the existing conventional steel drive shaft with suitable composite materials like E-Glass/Epoxy having high stiffness and high strength to weight ratio in addition of filler materials like 'CO' & General purpose resin, the composite drive shaft is fabricated manually by handy wrapping method. In this paper, an attempt has been made to investigate the characteristics of both conventional and composite drive shaft both theoretically and experimentally. The final results are then compared with each other and the results have marked with optimal characteristics for composite shaft than that of conventional shaft under equal load conditions. The Static and Dynamic analysis was carried out theoretically by using ANSYS Software.***

## I. INTRODUCTION

The present aims to design and fabricate a drive shaft made of composite material which could replace the conventionally available shaft for a bicycle. The composite drive shaft produced is made to undergo mechanical tests and is analyzed under static and dynamic load conditions with ANSYS tool. The entire work can be divided in to the following steps:

1.Design of conventional and composite drive shaft.
2.Methodology for preparation of test specimen.
3.Specimens under mechanical tests.
4.Analyzing the behavior of both conventional and composite drive shaft using FEA technique.
5.Comparision of results.

Fig. 1: Shaft driven bi-cycle.

The material properties are estimated for the e-glass/epoxy composite clothe fibre. The geometric model is modeled in ANSYS R14.5 plat form based on the dimensions of existing shaft. Then the model is

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fabricated. The present work is aims to design and fabricate a composite drive shaft which can replace the existing steel drive shaft. A shaft-driven bicycle is a bicycle that uses a drive shaft instead of a chain to transmit power from the pedals to the wheel arrangement. The shaft driven bikes have a large bevel gear, where-as a common bikes have a chain system to transmit power.

### Functions of the Drive Shaft

1.It must transmit torque from the transmission to the foot pedal.
2. During the operation, it is necessary to transmit maximum low-gear torque developed by the pedal.
3. The drive shafts must also be capable of rotating at the very fast speeds required by the vehicle.
4. The drive shaft must provide a smooth, uninterrupted flow of power to the axles.

Fig. 2: Driveshaft for a bi-cycle.

## 2. LITERATURE REVIEW

Shaft drives were introduced over a century ago, but were mostly supplanted by chain-driven bicycles due to the gear ranges. The first shaft drives for cycles appear to have been in United States and England. The Drive shafts are carriers of torque; they are subject to torsion and shear stress, which represents the difference between the input force and the load. They thus need to be strong enough to bear the stress.Most automobiles today use rigid driveshaft to deliver power from a transmission to the wheels. A pair of short driveshaft is commonly used to send power from a central differential, transmission to the wheels. Recently, due to advancements in internal gear technology, a small number of modern shaft-driven bicycles have been introduced.

## 3. DESIGN SPECIFICATIONS:

The following specifications were assumed suitably, based on the literature and available standards of bicycle drive-shafts: 1. The torque transmission capacity of the driveshaft (**T**) = 900 N-m.

2.The minimum bending natural frequency of the shaft ($f_{nb(min)}$) = 50 Hz.

3.Outside radius of the driveshaft ($r_o$)=6mm,length of shaft=295mm.

### 3.1 DESIGN OF CONVENTIONAL STEEL DRIVE-SHAFT:

**Torsional strength:** Since the primary load on a driveshaft is torsion, the maximum shear stress (**$\tau_{max}$**) at the outer radius (**$r_o$**) of the shaft is given by:

$$\frac{\tau_{max}}{F.S}=\frac{32Tr_o}{\pi[d_o^4-d_i^4]}$$

Assuming $T_{max}$ =90MPa and a factor of safety (**F.S**.)=3,we get

$$\tau_{max}=15600\text{MPa}$$

**Bending Natural Frequency:** According to Bernoulli-Euler beam theory, by neglecting shear deformation and rotational inertia effects, the bending natural frequency of a rotating shaft is given by:

$$f_{nb}=\frac{\pi p^2}{2L^2}\sqrt{\frac{EI_x}{m}}$$

$$m=\rho(\frac{\pi}{4})[d_o^2-d_i^2]$$

'ρ' is density of EN8 Steel=7800kg/$m^3$

'E' for EN8 steel=290GPa

$$m=0.88\text{kg/m}$$

$$I_x=\frac{\pi}{64}[d_o^4-d_i^4]$$

$$= 1.01 \times 10^{-9}\ m^4$$

Upon Substitution,

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$$f_{nb} = 55.3hz$$

### 3.2 DESIGN OF COMPOSITE DRIVE SHAFT:

**Torsional Strength:** Since the nature of loading is pure shear, 70% of the plies can be set at ±45° and the remaining 30% at 0º and 90º orientations.

$$\frac{\tau_{max}}{F.S} = \frac{T}{2\pi r^2 t}$$

Assuming $T_{max}$ =210 MPa,and a factor of safety (**F**.**S**.)=6,we get

$\tau_{max}$=1760.6MPa

**Bending Natural Frequency:**

$$f_{nb} = \frac{\pi}{2L^2}\sqrt{\frac{EI_x}{m}}$$

'ρ' is density of e-glass/epoxy=1900kg/$m^3$

'E' for e-glass/epoxy clothe=38700MPa

m=0.25kg/m

Upon Substitution, $f_{nb} = 45.5hz$

### 4.METHODOLOGY FOR TEST SPECIMEN PREPARATION:

Mild steel threaded rod of specification M8 has been considered. A mixture of general purpose resin with an accelerator which serves as a sticky glue is prepared. Small quantity of hardener like 'CO' is added to the mould. The mixture now serves as a perfect binding agent with the thorough mixture of the above chemical agents. The e-glass epoxy composite clothe is split into long pieces uniformly.

Fig 3: Conventional bicycle drive shaft

The threaded rod if fixed in the bench-vice and the prepared mixed resin is applied uniformly over the entire length of the rod by changing its position.

The splitted pieces of composite clothe is now wrapped along its entire length so as to assure perfect bonding between the threaded rod and clothe.After wrapping,the resin mixture is again applied onto the clothe which serves a fine layer.Similarly.the whole procedure is repeated with 12 layers of composite clothe with clothe fibre orientation angles as $0^0$ , $90^0, +45^0, -45^0$ each of three layers so as to produce a uniform solid cylindrical composite rod of 12mm diameter with 295mm length.The thickness of composite clothe fibre is about 0.31mm.

Fig.6:Wrapping of composite clothe,
Fig. 7: Resin applied layer by layer.

Fig. 8: Fabricated Composite Rod.

### 4.1 TORSION TEST:

**Composite drive shaft:**

Fig.9: Minimum Torque output- 42kgm,
Fig.10: Maximum Torque output- 148kgm

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### Conventional Steel Shaft:

Fig.11: Minimum Torque output-22kgm,
Fig.12: Maximum Torque output-85kgm

### 4.2 SHEAR TEST:

Fig. 13: Applied Load 30KN

Fig.14: Composite Specimen after failure

Fig.15: Steel Specimen after failure

## 5. MODELLING:

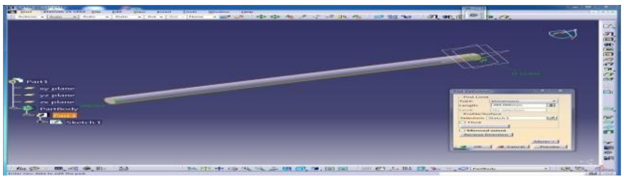

Fig.16: Catia Model of Specimen

## 6. FEA ANALYSIS:

### 6.1Torsion analysis of composite specimen

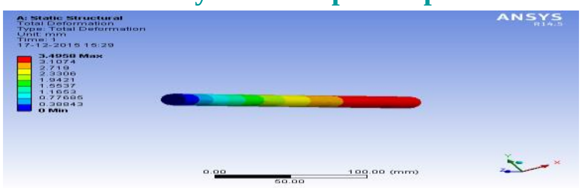

Fig.17: Maximum deformation

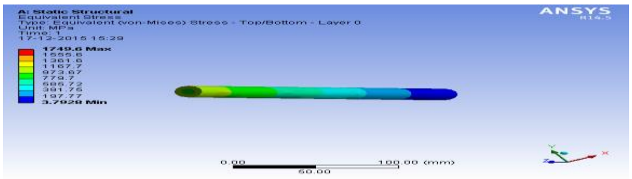

Fig.18: Von-misses stress

### Shear analysis of composite specimen

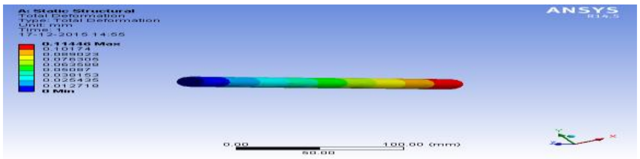

Fig.19: Maximum Deformation

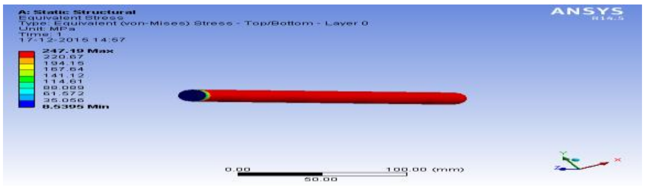

Fig.20: Von-misses stress

### 6.2 Torsional analysis of steel specimen:

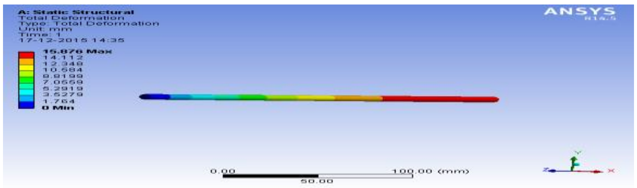

Fig.21: Maximum deformation

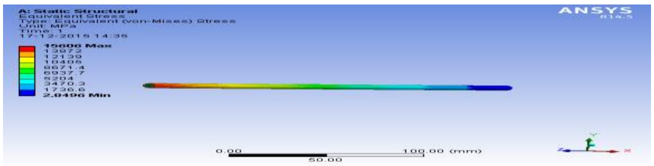

Fig.22: Maximum von-mises stress

### Shear analysis of steel specimen:

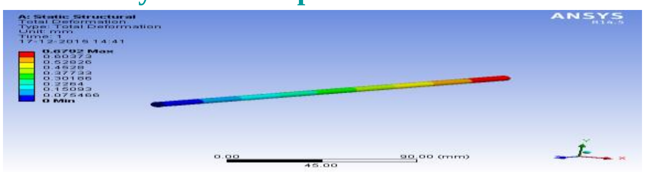

Fig.23: Maximum Deformation

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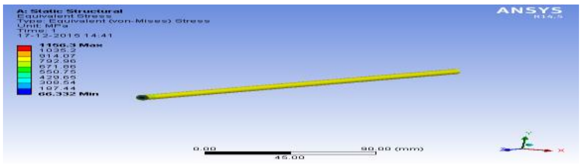


Fig.24: Von-misses stress

### 6.3 Dynamic analysis of composite specimen

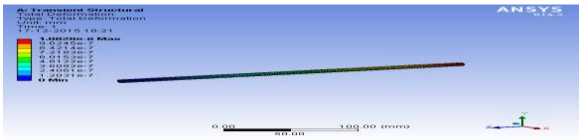


Fig.25: Maximum deformation

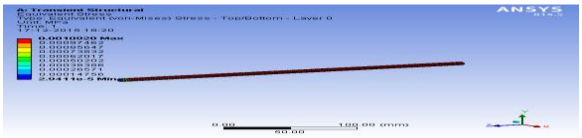


Fig.26: Equivalent Von-misses stress

### Dynamic analysis of steel specimen:

For Dynamic analysis a rotational speed of 800-1200 rpm is applied and analyzed for deformation and stresses.

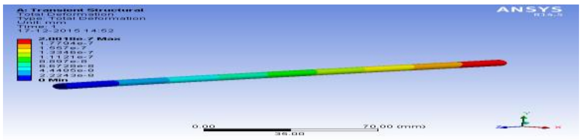


Fig.27: Maximum Deformation

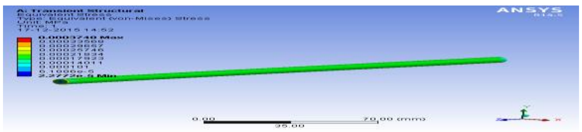
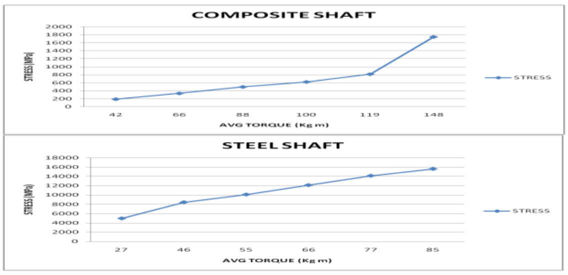


Fig.28: Equivalent Von-misses stress

## 7. COMPARISION OF RESULTS:




Graph 1: Torque (vs) Stress

| DEFORMATION (mm) | SHEAR STRAIN | SHEAR STRESS (MPa) |
|---|---|---|
| 0.11446 | 0.0015267 | 111.73 |

Table 1:Composite Shear Test (30KN)

| DEFORMATION (mm) | STRAIN | STRESS (MPa) |
|---|---|---|
| 1.0828e-9 | 6.2497e-9 | 0.0010928 |

Table 2: Composite Dynamic Test

| DEFORMATION(mm) | SHEAR STRAIN | SHEAR STRESS(MPa) |
|---|---|---|
| **0.6792** | **0.0085281** | **661.09** |

Table 3: Steel Shear Test (40KN)

| DEFORMATION(mm) | STRAIN | STRESS(MPa) |
|---|---|---|
| **2E-7** | **1.87E-9** | **0.0003748** |

Table 4: Steel Dynamic Test

## 8. CONCLUSION:

Composite shaft made from E-Glass/ Epoxy clothe fibre is fabricated and experimentation is done by taking torsion and shear load. For numerical study, the test specimens are modeled using CATIA software and analysed with FEA. After applying boundary conditions and torque, the torsional deflections are obtained for each torque value. List of the results are graphed. From the results,its clear that the composite rod performs much beter than conventional steel rod under torsion loads. The composite also performs almost equally to that of steel shafts under shear test . In conclusion, when the finite Element Analysis results compared with the theoretical results, the observations carried were successful and yield very small variations from the expected results.

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