DESIGN AND ANALYSIS OF COMPOSITE AUTOMOBILE DRIVE SHAFT

Shri. Kedar Deshpande [1], Prof. S. B. Patil [2]

[1]PG Scholar, Mechanical engineering , MET'S Institute of Engineering , Nashik, Maharastra , India
[2]Associate Professor, Mechanical engineering , MET'S Institute of Engineering , Nashik,,Maharastra , India

ABSTRACT

In Automobile field manufacture of automobile drive shafts are required to be smarter, as manufactured earlier conventionally. Drive shaft is basically manufactured using conventional material. In Automobile field manufacture of automobile drive shaft are required to be smarter as manufactured earlier conventionally. Drive shaft is basically manufactured using conventional material. Composite material provides a better alternative and also achieving weight reduction. In this present work attention is focused on study of theoretical and experimental work, torsional analysis on EN-8 steel drive shaft and Al-Glass fibre composite drive shaft. Study parameters like deflection, natural frequency under varying load using ANSYS will be done. Experimental testing will be done to torsional test machine noting Angle of Twist reflecting the deformation. Eventually weight reduction achieved is near to 30 %

Keyword *Composite Drive shaft1, Torsional analysis2,ANSYS3, CATIA4*

1. INTRODUCTION

Automobile industry has a wide spectrum of working components and accordingly materials required are also vast. Propeller Drive shaft (here after termed as Drive shaft) being one such important component it also vulnerable to material change from time to time. Drive shaft is an important part in it. It is also major power transmission part.

1.1 Drive shaft

Drive shafts are either Two –piece or a single piece. One end of drive shaft is joined to the engine output with U coupling and the other end is connected to the differential using square coupling. Some amount of power loss occurs due to joints at both the ends , but it is accepted owing to its need. Torque produced from the engine and transmissions is transferred to the rear wheels to push the vehicle in forward and reverse. It provide a smooth, uninterrupted flow of power to the axles. The drive shaft and differential are used to transfer torque. Drive Shaft arrangement in a Car Model is shown:

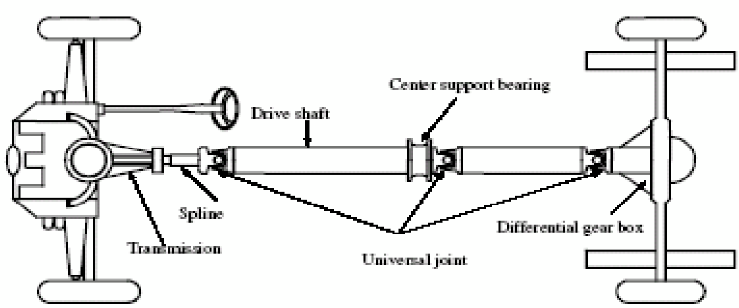


Figure 1: Two-piece Drive shaft present in a Driving system.

1.1 Information on Composite

Composite material is made up from two or three materials , either metallic or non metallic , and the resultant material possess all together new properties than that of individual material used . Traditional example are bricks which are primarily used for bearing the load .The list is long and present day modern technology has made easy to fabricate new and newer material . Composite material itself does not have specific shape and size and they take up the shaped of the newly fabricated material. Composite materials can be classified as:

- Polymer matrix composites
- Metal matrix composites
- Ceramic Matrix

2. LITERATURE REVIEW

For finalising the design procedure, information on manufacturing, a literature survey is conducted as under :

Sagar R Dharmadhikari, Sachin G Mahakalkar, Jayant P Giri, Nilesh D Khutafale et. al [1] have worked on steel. HS- Carbon/Epoxy and HM- Carbon/Epoxy as individual material for a conventional drive shaft , design for each material is worked out using standard Design procedure. ANSYS software is used and equivalent stress, Maximum shear stress and total deformation. And results will be feed in optimisation technique of GA- Genetic Algorithm and best solution is to be found out.
Pandurang V Chopde Prof. R.B.Barjibhe et. al [2] have studied design procedure for conventional drive shaft. Torsional and vibrational analysis is carried out. On SM45C, Carbon epoxy and glass epoxy composite FEA tool is used to check parameters like stress, deflection and natural frequency under load.
S. Mohan and M. Vinod et. al [3] have studied Design procedure for Drive shaft. Work is carried out on SM45C and Kevlar/Epoxy. ANSYS tool is used for stress, deflection etc. Design analysis and static analysis carried out and substitute material is suggested.
Naveenkumar Dasanagoudar1, Vinayak Koppad et. al [4] have mode efforts to provide weight reduction in automobile component viz. Drive shaft material under study is steel SM45C Aluminium - 6351-T6 and a composite material- Carbon fibre/Epoxy composite. CAD tools are used to generate 2D and 3D model and then it is analysed or Hypermesh, CATIA is used for 3D modelling. Analysis is performed are static, Buckling and Modal.
Dattatray S. Ghorpade, Kishor B. Kale et. al [5] have studied Design of Drive shaft and have used it on drive shaft of a commercial vehicle TATA 207. Material used is SM45C and Carbon/Epoxy 2D and 3D models are generated using CAD tool and analysis is performed using ANSYS software Final experimental result values are tabulated and conclusions are presented.
D.Dinesh, F.Anand Raju et. al [6] have optimised design parameters of a drive shaft and have suggested a low weight Drive shaft using composite material. Material taken for study are E-glass/epoxy HS-(High strength)-Carbon/Epoxy. Illustration of various glass fibres and aramide fibre is done in detail. Optimum design is attained and same parameters and optimised using Genetic Algorithm Technique.
Pankaj K. Hatwar , Dr. R.S. Dalu et. al [7] have studied properties of composite material and have used steel as SM45C, Carbon Epoxy and glass epoxy Drive shaft considered is of a heavy transport vehicle. Design analysis is done.2D and 3D models are generated and FEA tool- ANSYS is used in final, mass reduction achieved and cost comparison are made in detail.
Harshal Bankar, Viraj Shinde, P. Baskar et. al [8] have worked on conventional drive shaft used in SUV. Its dimensions and constraints are put in Design Consideration. Materials used for fabrication are SM45C, E glass HM Carbon E-glass polyester resin, and HS carbon. 2D and 3D models are generated in CATIA. Final analysis is done using ANSYS. Later effect of orientation of fibres on mechanical properties is demonstrated.
Thimmegowda Rangaswamy, Sabapathy Vijayarangan et. al [9] have proposed most valuable work in Design of Drive shaft. Use of composite material as drive shaft is successfully demonstrated material used is SM45C, E-glass/epoxy HM- Carbon/Epoxy. Design procedure and its analytical approach are demonstrated in detail. Further work is extended to find optimum sizing and stacking using Genetic Algorithm technique.
Arun Ravi [10] has studied Design procedure for a heavy transport vehicle drive shaft. Material used is SM45C, and HS Carbon/Epoxy and HM Carbon/Epoxy. 2D and 3D modelling is done and FEA tool is used for analysis.
Sunilkumar M. Bandgar , Nitin N. More et. al [11] have provided a review on hybrid Drive shaft use of composite material in drive shaft, Design procedure and optimum stacking sequence to be used in composite material.

Rohan D. Hucche, S.Y.Gajjal, V.K.Kulloli et. al [12] have worked on design of drive shaft used in a car. Composite material and steel material is used. Design is obtained and fabrication as per design. FEA tool is used for analysis.

3.SPECIFICATION OF DESIGN :

1. Length of Shaft = **0.4 m**
2. Outer diameter of Shaft = **0.028 m**
3. Inner Diameter of shaft = **0.024 m**
4. Ultimate Torque T = **59 Nm**
5. The minimum bending natural frequency of the shaft (fnb(min)) = 80 Hz.
6. Torque transmission capacity of shaft = **3500 Nm**

3.1. Important check for safe Design :

1. To check whether shaft is short or Long i.e, value obtained for the below equation is compared with 5.5 . and if value is greater than it is treated as Long shaft otherwise it is called as Short & Medium shaft

$$\frac{1}{\sqrt{1-\nu^2}} * \frac{L^2 t}{2r^3} > 5.5$$

2. The shaft needs to withstand torsional buckling (Tb) such that Tb > T
3. Torque transmission capacity should be more than 3500 Nm
4. Natural Bending frequency should be more than minimum bending natural frequency of the shaft - is 80 Hz

The fundamental natural bending frequency of drive shaft of passenger cars, small trucks, and vans should be higher than 6500 rpm to avoid whirling vibrations and the torque transmission capacity of the drive shaft should be larger than 3500 Nm.

The design should be based on the following criteria:

- Torque Transmission capacity of Drive Shaft :
- Torsional Buckling Capacity of Drive shaft.
- Lateral or Bending Vibration - Using Bernoulli's – Euler Beam Theory .

4. EVALUATION OF MECHANICAL PROPERTIES FOR COMPOSITE MATERIAL

For determining the Physical and Mechanical properties of the proposed new Composite an approach is followed based on the Principle of Rule of Mixture. In this principle the sharing of loads by the matrix and the fibre is dependent on the Volume – Weighted averages of the component properties . For ease of execution, aluminium used is treated as matrix and epoxy glass fibre which is used as reinforcement agent is termed as reinforcement fibre and finally achieved composite hollow shaft is treated as Composite . Subscript m,c and r are used to indicate properties of matrix, reinforcement fibre and composite .

Here the application is of hollow shaft nature resulting composite will be having hollow circular cross section . Volume and weight of the each three layer of aluminium and epoxy glass fibre is calculated and taken into further study . Table of the various parameters , their symbols for the each matric ,reinforcement fibre and composite are as below : Mechanical properties of Aluminium (6061-T6) and Unidirectional glass fibre epoxy composite (UGN150)

Table 1: Values calculated for Composite material

Property	Symbol and Unit	Value
Density	ρ (kg/m3)	2502
Poisson's ratio	M	0.318
Tensile modulus	E (GPa)	60.52
Tensile Strength	MPa	255
Fibre Load carrying capacity	In Percent	28.6186%
Shear modulus	G (GPa)	22.96
Shear strength	S_S (MPa)	146

5.ANALYTICAL CALCULATION FOR EN 8 SHAFT

Using values of EN-8 from standard data book . Standard Design procedure is followed and parameters are calculated like Torque transmission capacity , Maximum shear stress, Buckling Torque etc.

Table 2 : Properties Evaluated.

Properties	Units	Steel (EN – 8)
Torque transmission capacity	Nm	4579.9104
Maximum Shear Stress (τ_{max})	MPa	31.039488
Critical Stress (τ_{cr})	GPa	2.87238
Buckling Torque (T_b)	Nm	7074.701744
Bending Natural frequency (f_{nb})	Hz	464.7931
Critical Speed (N_{cr})	Rpm	27887.586
Mass (m)	Kg	0.51295924

6.ANALYTICAL CALCULATION FOR COMPOSITE SHAFT

Using values from Table 1 ,. Standard Design procedure is followed and parameters are calculated like Torque transmission capacity , Maximum shear stress, Buckling Torque etc

Table 3: Properties Evaluated.

Properties	Units	Composite
Torque transmission capacity	Nm	4299.81
Maximum Shear Stress (τ_{max})	MPa	37.897216
Critical Stress (τ_{cr})	GPa	3.2980009
Buckling Torque (T_b)	Nm	8529.1551702
Bending Natural frequency (f_{nb})	Hz	401.8052
Critical Speed (N_{cr})	Rpm	24108.31408
Mass (m)	Kg	0.36157218

7. FINITE ELEMENT ANALYSIS USING ANSYS

7.1 Fea On En 8 Shaft At 59000 Nm

Model is imported from the CATIA model in igs. Format and after successive steps result are :

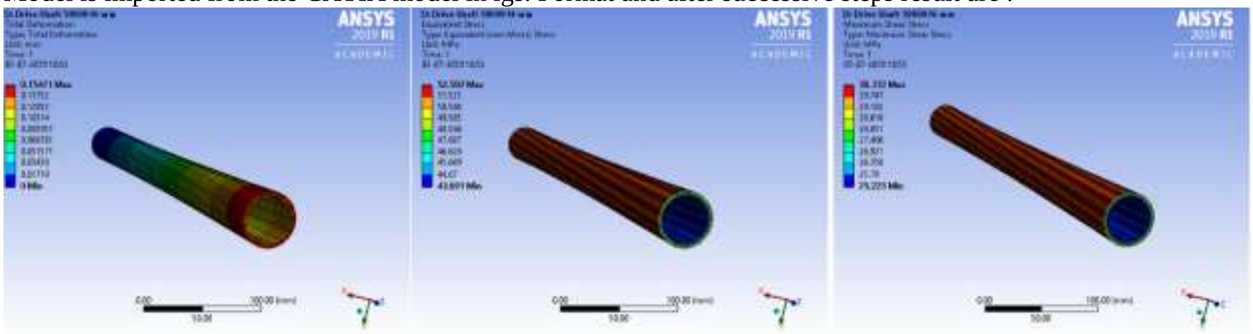


Figure 2 :Combined figure of Total Deformation ,Equivalent Stress and Shear Stress on EN-8 at Torque 59 Nm

The values obtained in ANSYS are tabulated as under :

Table 4 : Result table from ANSYS on EN-8 at Torque of 59 Nm

	Unit		Values
Total Deformation	in mm	Max	0.15471
		Min	0
Equivalent stress	in MPa	Max	52.502
		Min	43.691
Shear Stress	in MPa	Max	30.312
		Min	25.225

7.2 FEA on Composite Shaft At 59000 Nmm

Model is imported from the CATIA model in igs. Format and after successive steps result are :

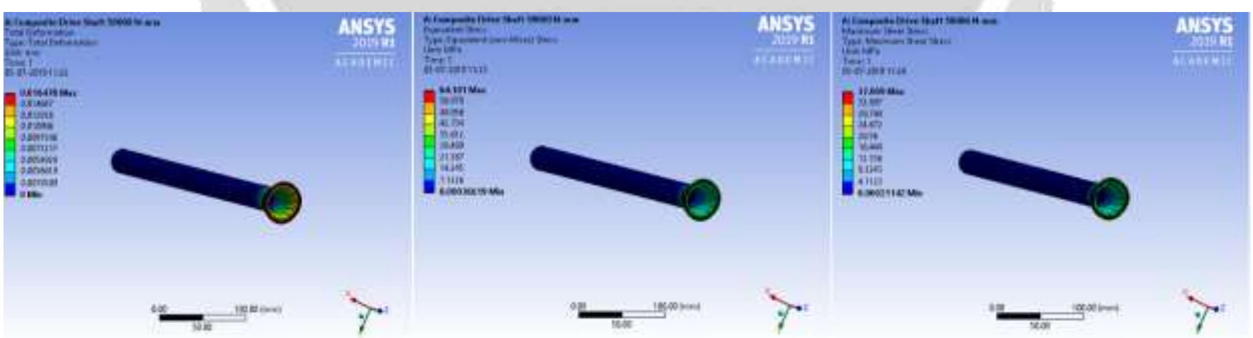


Figure 3.Total Deformation, Equivalent Stress and Shear stress on Composite Drive shaft at 59 Nm

The values obtained in ANSYS are tabulated as under :

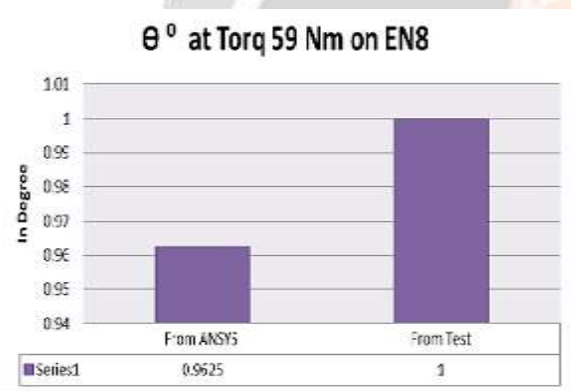
Table 5: Result table from ANSYS on Composite at Torque of 59 Nm

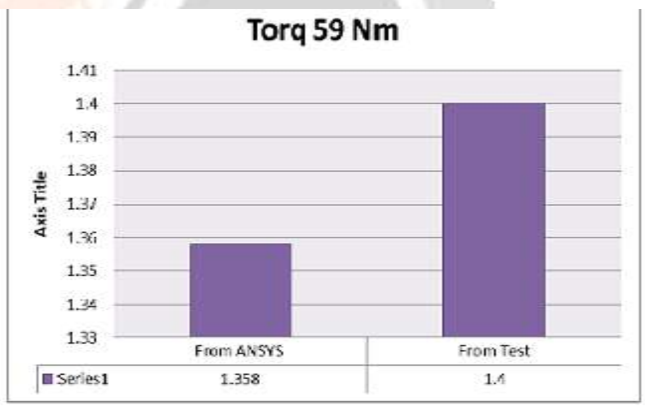
	Unit		Values
Total Deformation	in mm	Max	0.016478
		Min	0
Equivalent stress	in MPa	Max	64.101
		Min	0
Shear Stress	in MPa	Max	37.009
		Min	0

8 TEST AND VALIDATION :

Comparison of Ө⁰ from ANSYS value and Experimental Test

From both the ANSYS and Experimental test, comparison of Angle of Twist is done. It is direct measurement of Torsional deformation. On Drive shaft of EN- 8 and Composite material are to be found first Values of Angle of Twist

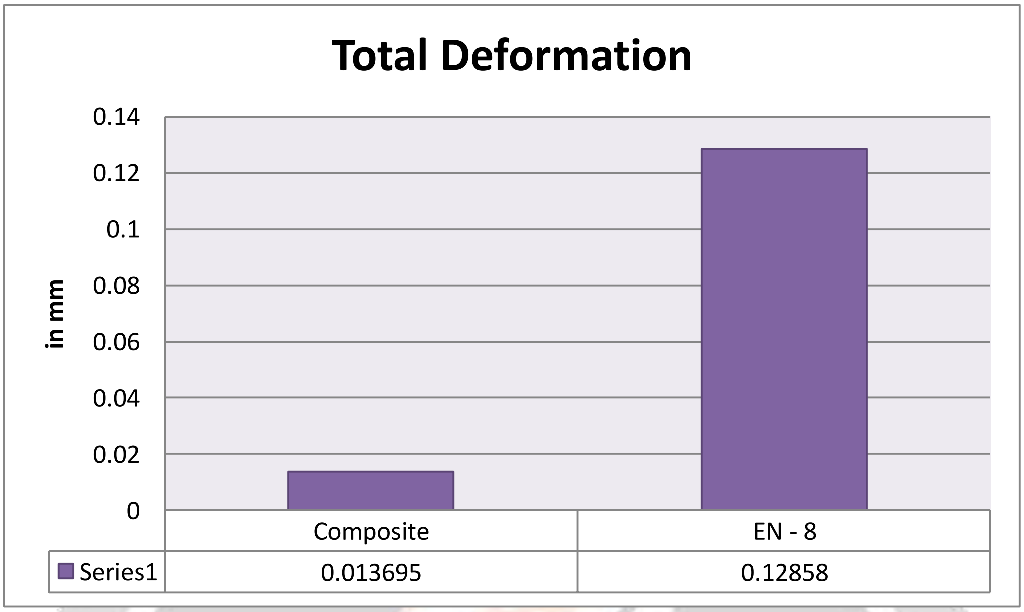




Graph 1. . Angle of Twist of EN 8 at Torque of 59 Nm. And **2** : Angle of Twist of Composite at Torque of 59 Nm.

From both the graph it can be concluded that Angle of twist are not indifferent at torque application of 59 Nm.

8.2 Total Deformation of both Shaft from ANSYS at 49 Nm and 59 Nm



Graph 2 : Comparative Total Deformation of both Shafts at Torque of 59 Nm

From graph 2. major fact is noted that Composite shaft undergoes very little Deformation and it proves its applicability in replacement of EN -8 by this Composite material suggested.

8.3 Comparison of Mass from Experimental, ANSYS and Analytical approach.
After actual fabrication mass of each shaft was noted. Values found were:

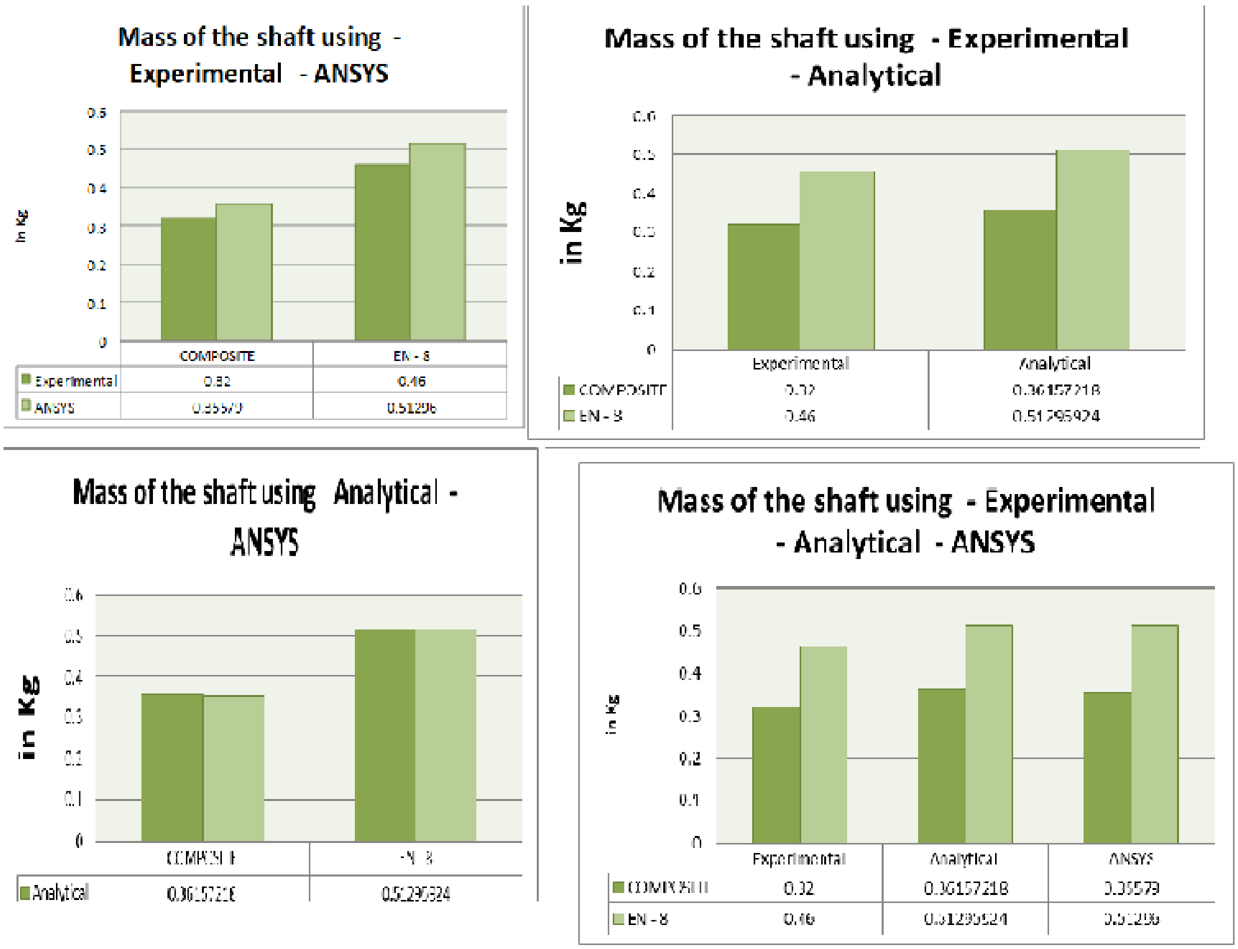
- Mass of EN 8 shaft = **0.46 Kg**
- Mass of Composite Shaft = **0.32 Kg**

Analytical values are :

- Mass of EN 8 shaft = **0.51295924 Kg**
- Mass of Composite Shaft = **0.36157218 Kg**

Using FEA tool mass value for both the shaft obtained are

- Mass of EN 8 shaft = **0.51296 Kg**
- Mass of Composite Shaft = **0.35579 Kg**



Graph3. Comparative of Mass both Shafts Experimental Vs ANSYS Vs Analytical

8.4 Conclusion from Graphs of Mass

Composite material developed for the application here have displayed good mechanical Properties. Its Properties are evaluated and tabled in Table no. 5 .Total Deformation result display very small amount of deformation for Composite drive shaft. It is found that weight reduction of Composite shaft over EN-8 is achieved are :

Using ANSYS is **30.634%** Experimentally is **30.43 %** Analytically **28.81 %.**

This reduced mass of the Automobile component will definitely lead to increased fuel efficiency.

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