FEA & Experimental analysis of Glass Fiber composite propeller shaft

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Abstract — *This paper presents the feasibility of composite shaft over conventional steel shaft of automobile. In this study, Maruti Omni's steel shaft is replaced with the glass fiber composite shaft which is designed, analyzed and tested for multiple torque values. Results for FEA Calculation show stress induced on of composite shaft is less compared to the Mild steel shaft. Also the weight reduction of the composite drive shaft to that of conventional shaft is 67 % by numerical method and by experimentally it is 72 %. Finally, results for FEA, Analytical and Experimental Calculation shows stress of composite shaft is lesser than that of conventional steel shaft. Also the weight of the composite drive shaft is less than that for the conventional shaft.*

Keywords — *shaft design, Composite, Torsional strength.*

I. INTRODUCTION

There is a need of finding an alternate solution for the regular or the conventional materials used in the field of engineering because of rapid advances in the technology. The design engineers are naturally forced to search for better and more reliable materials than the conventional ones. A constant lookout for durable and strong materials is done by the designers and the researchers in the field to provide better solutions for the fellow engineers. [3]

A transmission shaft or a drive shaft of a vehicle is a mechanical component for rotation and transmission of torque from engine to the gearbox. it is used to connect other components of a drive train such as transmission gearbox to the differential gearbox, that cannot be connected directly as the components are far from each other. Drive shafts carry torque. They are under the constant action of torsion and shear stress, which is equivalent to the difference between the input torque and the load. [2] This makes it very important for the shaft to be strong enough to bear the stress, at the same time we also need to avoid too much additional weight as it would increase the inertia of the vehicle.

Drive shaft is been used in the automobiles. They are mainly used in the commercial vehicles such as vans, trucks, SUV's etc. There should be a medium from where the motion from engine is been transferred to the rare wheels. To transfer this motion from the engine to the rare wheels, drive shaft plays an important role.[1] Whenever the distance between the engine and rare wheels is more than 1.5m use of two-piece drive shaft is been used. Drive shaft is one of the important parts of the vehicle, without which we cannot transfer motion from engine to the rare wheel smoothly.

II. METHODOLOGY

After referring to multiple references it was understood that how composite drive shaft having optimum weight can be selected using the exact methodology.

For this process we use CATIA V5 R20 and ANSYS workbench 14.5 software.

- CAD model of conventional drive shaft is prepared in CATIA V5 R20 as per actual
- Dimension. Then this model is imported to ANSYS workbench 14.5 software. For pre-processing and to derive a final solution results are derived from ANSYS software.
- CAD model of composite drive shaft is prepared in CATIA V5 R20 as per actual dimension. Then this model is imported in ANSYS workbench 14.5. For pre-processing and to derive a final solution results are derived from ANSYS software.
- Compare conventional drive shaft and composite drive shaft results
- For validation, we require the results derived from theoretical and experimental calculations.
- To perform the experiment, we manufacture the sample composite material and conventional drive shaft. Testing of these two shafts is been done in torsion test machine and the results are been derived.
- Later CAD model for these two shafts having same dimensions was been generated and was imported in ANSYS. Results were derived after this process and were compared with the experimental results.
- Theoretical calculations for sample conventional and composite drive shaft were calculated.
- Lastly ANSYS, theoretical and experimental results were compared and preferable shaft was selected in automobile.

III. DESIGN OF COMPOSITE SHAFT

We have studied the design of original Omni shaft and checked its safety by FOS. We now have to design the composite shaft and check if it comes out safe and to make the required changes in the dimensions to the original shaft dimensions.

D = 51mm, L = 720mm, T = 59000Nmm,

T_{12ut} = 72MPa

d =**?**

$$\frac{Fs}{R} = \frac{T}{Ip}$$

$$\frac{72}{\frac{51}{2}} = \frac{59000}{\frac{\pi}{32}(51^4 - ID^4)}$$

ID ≈ 27.783

ID = 28 mm

Now find the stress generated due to the composite shaft of new dimensions

$$\mathrm{Ip} = \frac{\pi}{32}(\mathrm{D}^4 - \mathrm{d}^4)$$

$$\mathrm{Ip} = \frac{\pi}{32}(51^4 - 28^4)$$

Ip = 60.3828 * 103 mm4

$$\frac{\mathrm{T}}{\mathrm{Ip}} = \frac{\mathrm{C}\Theta}{\mathrm{L}}$$

For T = 59000Nmm

$$\frac{\mathrm{T}}{\mathrm{Ip}} = \frac{\mathrm{C}\Theta}{\mathrm{L}}$$

$$\frac{59000}{60.3828 * 10^3} = \frac{4.14 * 10^3 * \Theta}{720}$$

Θ = 0.1818rad

$$\frac{\mathrm{Fs}}{\mathrm{R}} = \frac{\mathrm{C}\Theta}{\mathrm{L}}$$

$$\frac{\mathrm{Fs}}{25.5} = \frac{4.14 * 10^3 * 0.1818}{720}$$

Fs = 26.669MPa

FOS = allowable shear stress of GF/FS = 72/26.669

FOS = 2.7

Hence, the design is safe.

IV. FINITE ELEMENT ANALYSIS

The boundary conditions applied to the composite shaft are shown below:

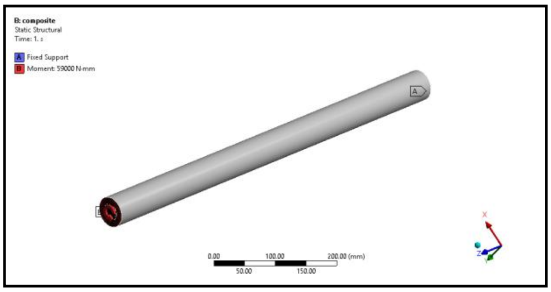

Fig 1 Boundary Conditions

One end of the shaft is fixed support, and a torque of 59000Nmm is applied at the other.

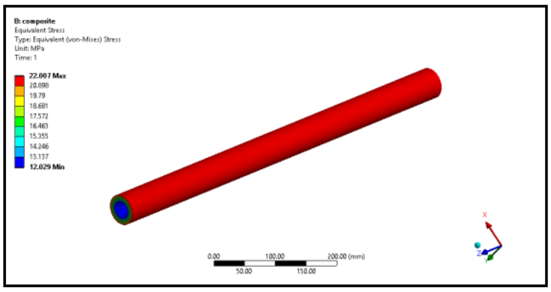

Fig 2 Stress Distribution

Equivalent stress in the Composite shaft is 22.007Mpa, when torque of 59000Nmm is applied.

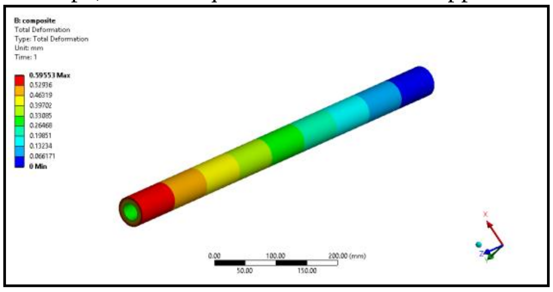

Fig 3 Deformation

The deformation in Composite shaft at 59000Nmm torque is 0.59553mm.

V. EXPERIMENTAL SETUP

A. *Prototyping and Scale selection*

The machine used for testing is Torque Testing Machine. The machines were unavailable for original shaft length of 720mm. The length of shaft for testing on available machines is less than 500mm. Hence, we make a prototype of the original shaft by scaling down the dimensions. The length of the prototype is reduced to 400mm. Hence, the scaling factor is calculated as,

$$\text{Scaling factor} = \frac{length\ of\ original\ shaft}{length\ of\ prototype} = \frac{720}{400} = 1.8$$

The **scaling factor** used to make the prototype is 1.8.

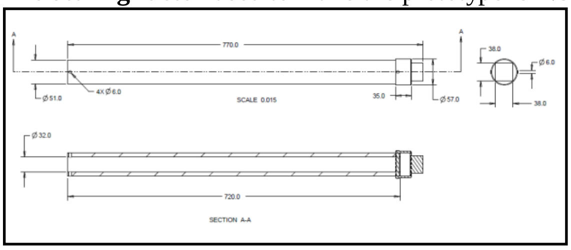

Fig 4 2D draft of Prototype

Fig 5 Final Product

Final product after all the manufacturing stages.

B. Manufacturing and Testing

For fabrication of composite drive shaft, we have used the composition of Fibres and Matrix. For present work we have used Glass fibre and Epoxy as a resin.

Fig 6 Hand Lay-up Technique

C. Force Measurement

For experimental analysis, we need to perform the testing. For different load stress needs to be calculated. Torsion machine is used for analysis. But through this machine we cannot calculate the stress directly. Main factor to calculate the stress is the twisting angle. With the help of torsion testing machine, we can obtain the actual twisting angle. Stress can be calculated by substituting this twisting angle in the formula to calculate the stress. To obtain the twisting angle, following twisting machine is used,

Table I Machine Specifications

Max. Torque Capacity	100 Nm
Least count	0.01
Type	Digital
Clearance between Grips	500 mm
Grip width	8-25 mm
Motor	0.5 HP
Voltage	440 V
Frequency	50 Hz

Figure 7 Torque testing Machine

D. Experimental Procedure

Mild steel rod is mounted on machine for torsion test followed by step by step applying of torque. Following torques are been applied for the test: 10787Nmm, 21575Nmm, 34323Nmm, 49033Nmm, 59000Nmm

Twisting angle is been measured for each applied torque. Release the torque and un-mount the Mild steel material from the machine. Glass fiber rod is mounted on machine for torsion test followed by step by step applying of torque. Twisting angle is been measured for each applied torque. Release the torque and un-mount the Glass fiber material from the machine.

Table II Twisting Angle and Corresponding Stresses

	MS (SM45C) shaft		Composite shaft	
Torque (N mm)	Twisting angle (°)	Stress (M Pa)	Twisting angle (°)	Stress (N/mm^2)
10787	0.2	9.688	1	2.49
21575	0.3	14.53	2	4.98
34323	0.4	19.37	3	7.48
49033	0.5	24.22	4	9.98
59000	1	33.14	6	15.398

VI. RESULTS

The table below shows the result comparison of both original MS shaft of Maruti Omni and the new designed Glass fiber shaft.

Table III Result Comparison of MS and GF

	MS (SM45C) shaft	Composite shaft
Shear stress	59.652MPa	27.716MPa
Outer diameter	51 mm	51 mm
Inner diameter	32 mm	28 mm
Length	720 mm	720 mm
Weight	7 kg	2.2 kg
Weight Saving	N/A	67 %

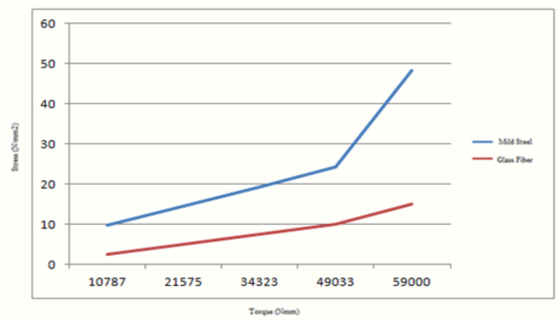

Fig 8 Comparison of Stress Distribution in MS and GF shaft

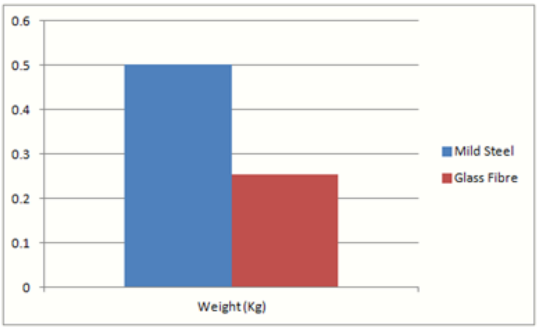

Fig 9 Weight Comparison

Results for FEA Calculation show stress induced on composite shaft is less compared to the Mild steel shaft. Also the weight reduction of the composite drive shaft to that of conventional shaft is 67 % by numerical method. Experimentally the weight reduction is 72 %.

Finally, results for FEA, Analytical and Experimental Calculation shows stress of composite shaft is lesser than that of conventional steel shaft. Also the weight of the composite drive shaft is less than that for the conventional shaft.

Comparison also shows that the results derived using all the above methods are Similar to each other. Hence, FEA results can be considered as valid method for design purpose.

VII. CONCLUSION

Following A comparative study has been made between steel and composite shaft to find out material having high strength to weight ratio. From the results obtained it is concluded that,

1. Stress occurred in the composite drive shaft is less as compared to conventional drive Shaft by 53.5%.
2. Results obtained through ANSYS are validated from analytical calculations and experimental testing.
3. Comparison of the results also shows that the results derived using all the calculation methods are similar to each other. Hence, FEA results can be considered as valid method for design purpose.
4. Composite Glass fibre shaft has less weight than conventional steel drive shaft for analyzed stress. So composites can be suggested for driving shaft of light passenger vehicle.
5. 67% weight reduction in shaft weight suggests that the overall kerb weight can be reduced drastically.
6. The replacement of conventional drive shaft results in reduction in weight of automobile

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