# Designe and Analysis of Propeller SHAT By Using KEVLOR/EPOXY Composite

Thahar Ali Syed [1*] Adnan Javed [2] Kasala Raju[3] Naga Raju M[4]

**ABSTRACT:** In the design of automobiles, the industry is exploring composite materials in order to obtain reduction of weight without significant decrease in vehicle quality and reliability. This is due to the fact that the reduction of weight of a vehicle directly impacts its fuel consumption. Particularly in city driving, the reduction of weight is almost directly proportional to fuel consumption of the vehicle. Thus, in this project work the entire drive shaft assembly of a Toyota Qualis was chosen and analyzed by replacing it with composite and hybrid materials. The following materials were chosen

- Steel
- Boron/Epoxy Composite
- Kevlar/Epoxy Composite
- Aluminium – Glass/Epoxy Hybrid
- Carbon – Glass/Epoxy Hybrid

The analysis was carried out for three different ply orientations of the composites in order to suggest the most suitable ply orientation of the material that would give the maximum weight reduction while conforming to the stringent design parameters of passenger cars.

## I. Introduction

In the process of designing a vehicle, one of the most important objectives is the conservation of energy and the most effective way to obtain this goal is the reduction of weight of the vehicle. There is almost a direct proportionality between the weight of the vehicle and its fuel consumption, particularly in city driving. The automotive industry is exploiting composite material technology for structural component construction in order to obtain reduction of weight, without decrease in vehicle quality and reliability. The advanced composite materials seem ideally suitable for long power drive shaft (propeller shaft) applications as their elastic properties can be tailored to increase the torque they carry as well as the rotational speed at which they operate. In this project, the conventional drive shaft material has been replaced with advanced composites and hybrid materials to carry out a comparative analysis, thus determining the most suitable replaceable material.

### 1.1 Specification of Problem:

- The first was Steel (SM45C) which was used for reference purpose
- Two Composites Boron/Epoxy, Kevlar/Epoxy And Hybrid shafts i.e., a combination of Aluminium and

Almost all automobiles (which correspond to design with rear wheel drive and front engine installation) use a drive shaft for the transmission of motion from the engine to the differential. An automotive propeller shaft, or drive shaft, transmits power from the engine to differential gears of a rear wheel-driving vehicle. The static torque transmission capability of the propeller shaft for passenger cars, and small truck and vans should be larger than 3500 Nm and the fundamental bending natural frequency should be higher than 8000rpm to avoid whirling vibration. The whirling of the propeller shaft, which is a resonance vibration, occurs when the rotational speed is equal to the fundamental natural bending frequency**,** which is inversely proportional to the square root of specific stiffness (E/ρ).When conventional materials such as Steel or Aluminium are used, the weight of the drive shaft assembly is considerably high, which has a certain role in increasing the overall weight of the vehicle. Also, due to the increased weight of the shaft there are more chances of whirling of the shaft. To avoid this in conventional drive shafts, which have a length exceeding 1.2m, the shafts are made in two pieces. However, the two piece steel propeller shaft has a complex and heavy configuration because three universal joints and a center support bearing in addition to a spline are required, which produces noise and vibrations that are transmitted to vehicle through the center support bearing.

### 1.2 Aim and Scope of the Work

The project aims to reduce the weight of the drive shaft assembly by using advanced composite materials. For this project work, the drive shaft of a Toyota Qualis was chosen. The modeling of the drive shaft assembly was done using CATIA V5R16. A shaft has to be designed to meet the stringent design requirements for automobiles. A comparative study of five different materials was conducted to choose the best-suited material. Steel (SM45C) was chosen for reference and the rest of the four composites were analyzed at three different ply orientations. The material properties of the composites were obtained based on the Classical Lamination Theory with the help of a code written in C language. The analysis was carried out using ANSYS 11.0 WorkBench for the following materials at three different ply orientations $[0/30]_{8S}$ , $[\pm45]_{8S}$ and $[0/90]_{8S}$

Glass/Epoxy Composite,Glass/Epoxy and Carbon/Epoxy.

### 1.3 Drive Shaft

The term Drive shaft is used to refer to a shaft, which is used for the transfer of motion from one point to another. Whereas the shafts, which propel (push the object ahead) are referred to as the propeller shafts. Propellers are usually associated with ships and planes as they are propelled in water or air using a propeller fan. However the drive shaft of the automobile is also referred to as the propeller shaft because apart from transmitting the rotary motion from the front end to the rear end of the vehicle, these shafts also propel the vehicle forward. The shaft is the primary connection between the front and the rear end (engine and differential) which performs both the jobs of transmitting the motion and propelling the front end. Thus, the terms Drive Shaft and Propeller Shafts are used interchangeably.

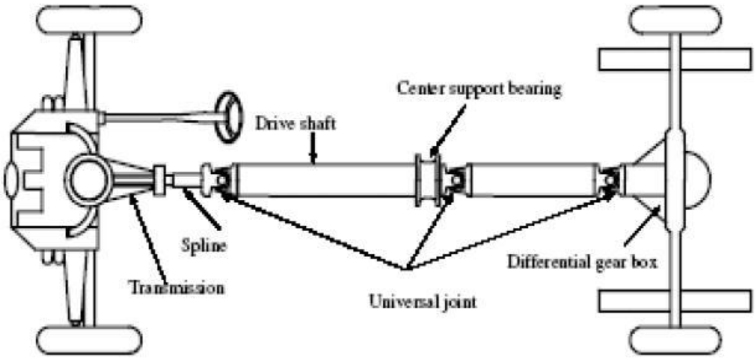



fig Schematic arrangement of Underbody of an Automobile

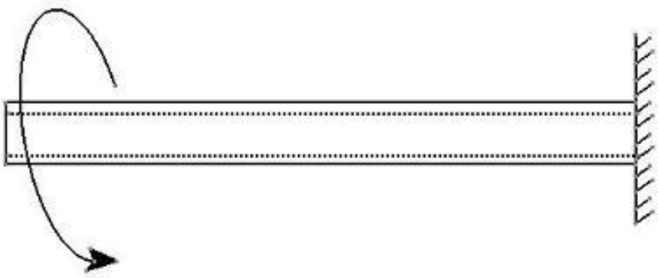
## II. THEORETICAL AND SIMULATED RESULTS CORRELATION

A comparison between the results obtained based on theoretical calculations and the results obtained from the ANSYS 11.0 WorkBench has been carried out. For this purpose, the drive shaft of the automobile has been idealized as a hollow cylindrical shaft. It is then subjected to the same load theoretically and in the finite element solver. The comparison of results shows a very close range conformance, which has been plotted.

### 2.1 Theoretical Calculations for Hollow Shaft

The Drive shaft, for simplicity has been first idealized as a hollow cylindrical shaft which is fixed at one end and on which a torque of 3500 Nm is applied as represented below.

For the hollow shaft, Let
$R_o$ = 0.01 m ; $R_i$ = 0.02 m ; l = 0.5 m ; E = 207e9 pa and Torque=3500 Nm
Where $R_o$ = Outer Radius $R_i$ = Inner Radius l = Length of the shaft
E = Young's Modulus of Steel (SM45C) T = Applied Torque



Hollow Shaft being subject to a Torque of 3500 Nm

$$Deflection = Y_{Max} = \frac{ML^2}{2EI} = \frac{3500\ \mathrm{X}(0.5^2)}{2\ \mathrm{X}\ (207e^9)\mathrm{X}\ (1.178e^{-7})} = 0.0179m$$

Then:
$Maximum\ Shear\ Stress$:

$$\tau_{\mathrm{Max}} = \frac{\mathrm{T} \times \mathrm{R}_0}{\mathrm{J}} = \frac{3500 \times 0.02}{\left[\frac{\pi}{2}\right] \times [R_0^4 - R_i^4]} = \frac{70}{2.35626 \times 10^{-7}} = 2.9708\ e\ 8\ Pa$$

$Maximum\ Von - Mosses\ Stress$

$$=\frac{\left[T\times\left(\frac{d_o}{2}\right)\right]}{I}$$

$$=\frac{3500\times(0.04/2)}{\left[\frac{\pi}{64}\right]\times[(0.04)^4-(0.02)^4}$$

=594178454.2

**Simulated Results for Hollow Shaft**

The derived theoretical results are now going to be compared to the simulated results. For which, a hollow shaft with the same specifications was created in CATIA V5R17. This CATIA model was then imported into ANSYS 11.0 Workbench, wherein the model was analyzed. The same torsional load was applied by fixing one end of the shaft and applying torque on the other end. The results were found to be very close to the theoretically calculated values. The results are as follows.

The hollow shaft is made-up using the same dimensions, which are

$R_o$ = 0.01 m ;$R_i$ = 0.02 m ; l = 0.5 m ; E = 207e9 pa and Torque=3500 Nm

**Ansys Results**

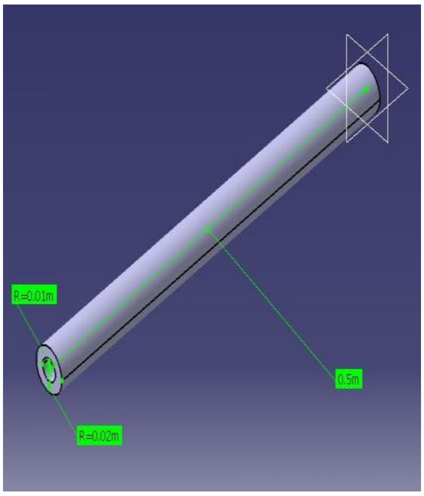



Fig A: Catia Model of Hallow shaft

**Material properties**

= 5.9417e7Pa

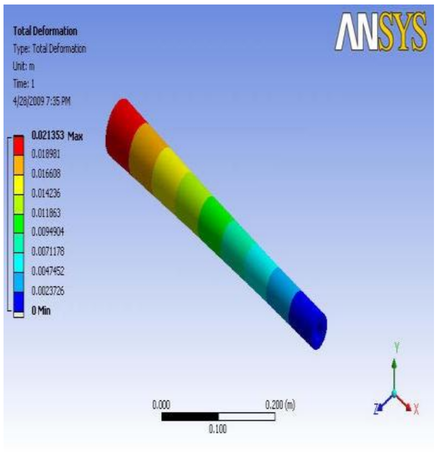



Fig B: Total deformation

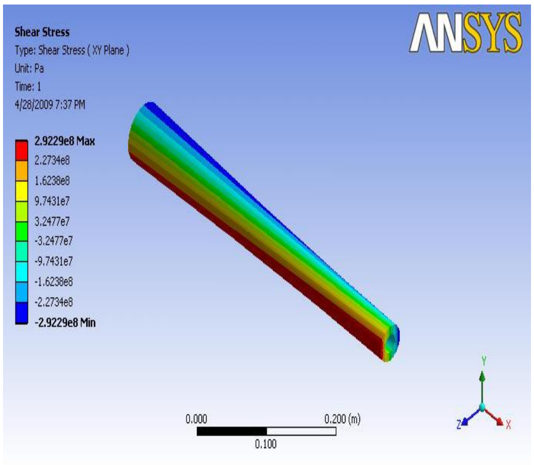



Fig C: Shear stress

## III. ANALYSIS

Since the domain for analysis is a complex assembly of a number of parts, ANSYS 11.0 Workbench was chosen for performing the analysis. The proper connection between each part of the assembly and the subsequent connectivity of mesh is the key criteria for getting proper load transfers throughout the assembly. The Workbench module of ANSYS 11.0 does not require the explicit specification of element types by the user, depending upon the assembly, the element types are chosen by the solver to get the best possible results. But for the dominating major portion of the assembly which is relatively easier to manufacture, the composite material were applied. The CATIA assembly, imported into ANSYS is subjected to

I. Torsional Analysis
II. Modal Analysis &
III. Harmonic Analysis

This is to be carried out on a total of five materials out of which four are composites at ply orientations of $[0/30]_{8\,S}$ , $[+/-\,45]_{8\,S}$ and $[0/90]_{8\,S}$

Drive Shaft Assembly in ANSYS Workbench

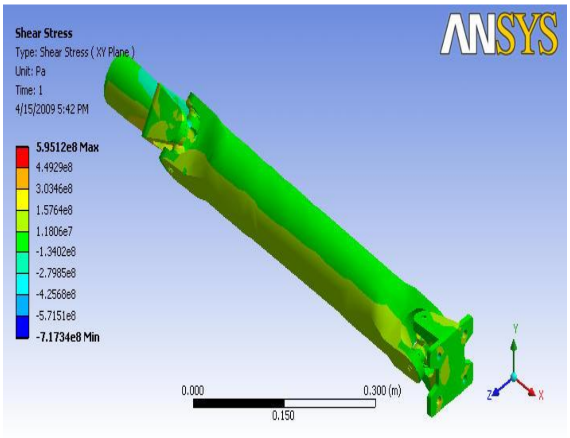
**Element Types**

The element types allotted based on the geometry of the assembly by the ANSYS solver are as follows

| Generic Element Type Name | ANSYS Name | Description |
|---|---|---|
| 10 Node Quadratic Tetrahedron | Solid187 | 10 Node Tetrahedral Structural Solid |
| 20 Node Quadratic Hexahedron | Solid186 | 20 Node Structural Solid |
| Quadratic Quadrilateral Contact | Conta174 | 3D 8 Node Surface to Surface Contact |
| Quadratic Quadrilateral Target | Targe170 | 3D Target Segment |
| Quadratic Triangular Contact | Conta174 | 3D 8 Node Surface to Surface Contact |
| Quadratic Triangular Target | Targe170 | 3D Target Segment |

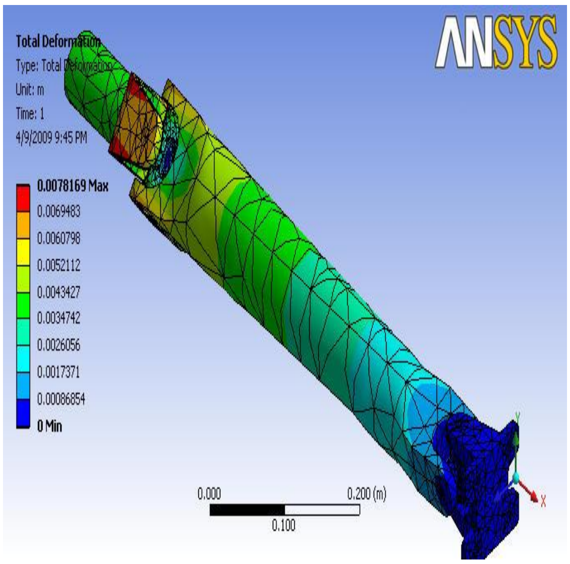
Deformation Shear Stress

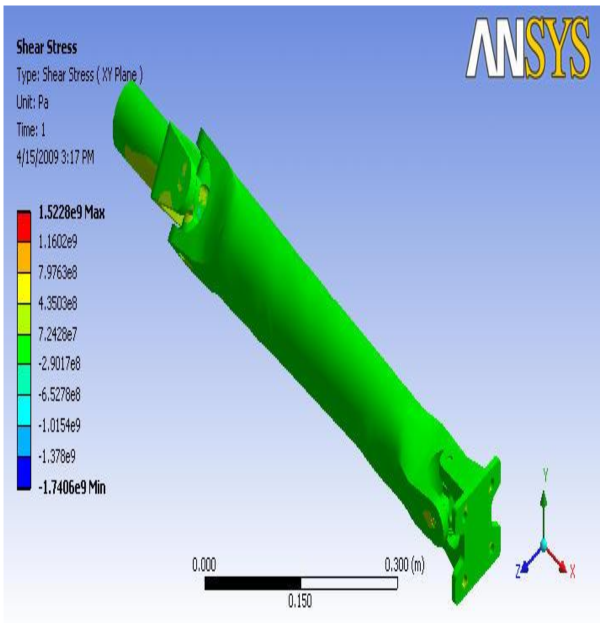
**Boron/Epoxy**




**Ply Orientation : $[0/30]_{8\,S}$**

**D**eformation Shear Stress



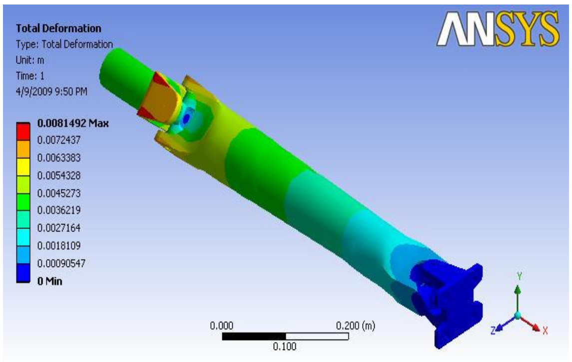



Kevlar/Epoxy

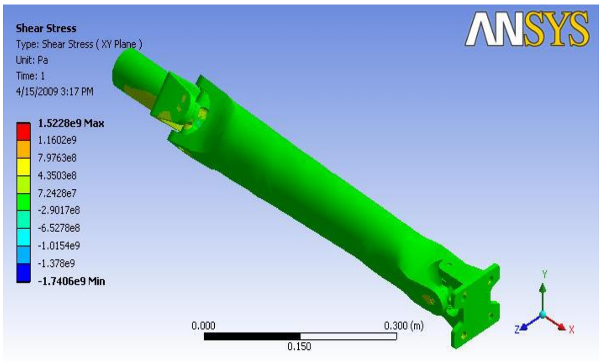
**Ply Orientation : $[0/30]_{8\,S}$**

**Hybrid Drive Shaft (Aluminum & Glass/Epoxy) Ply Orientation: $[0/30]_{8\,S}$**

Deformation

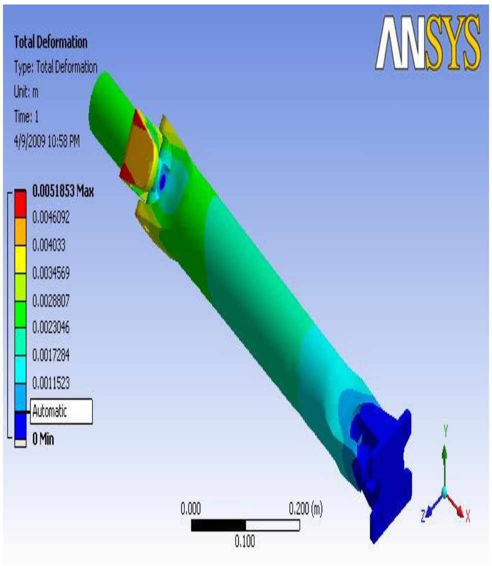


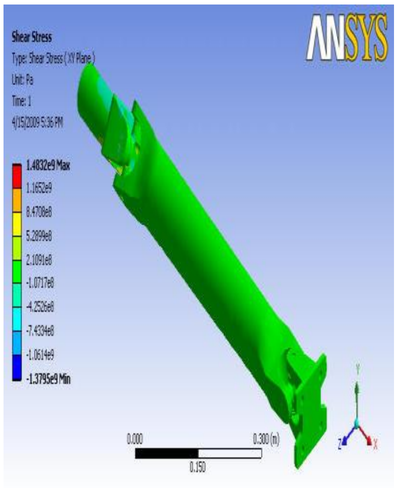

Shear Stress




MODAL ANALYSIS

**1 Steel (SM45C)**



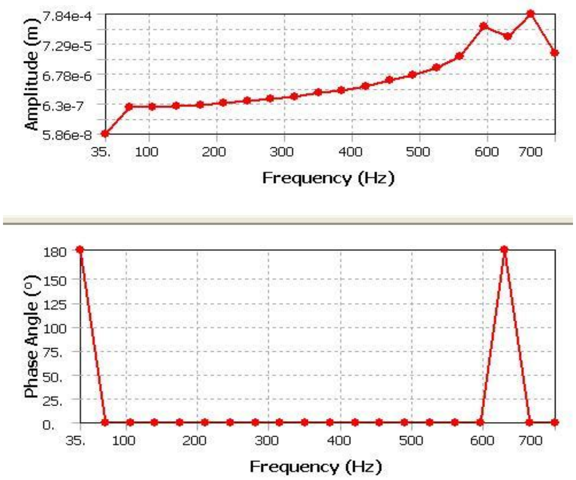

Deformation

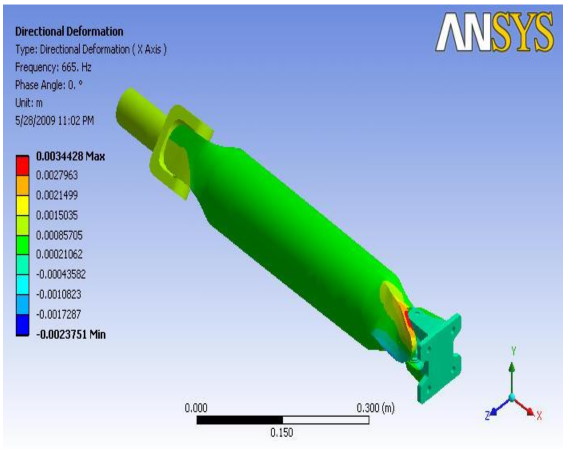
Shear Stress

**Frequency Response**

**2 Boron/Epoxy**

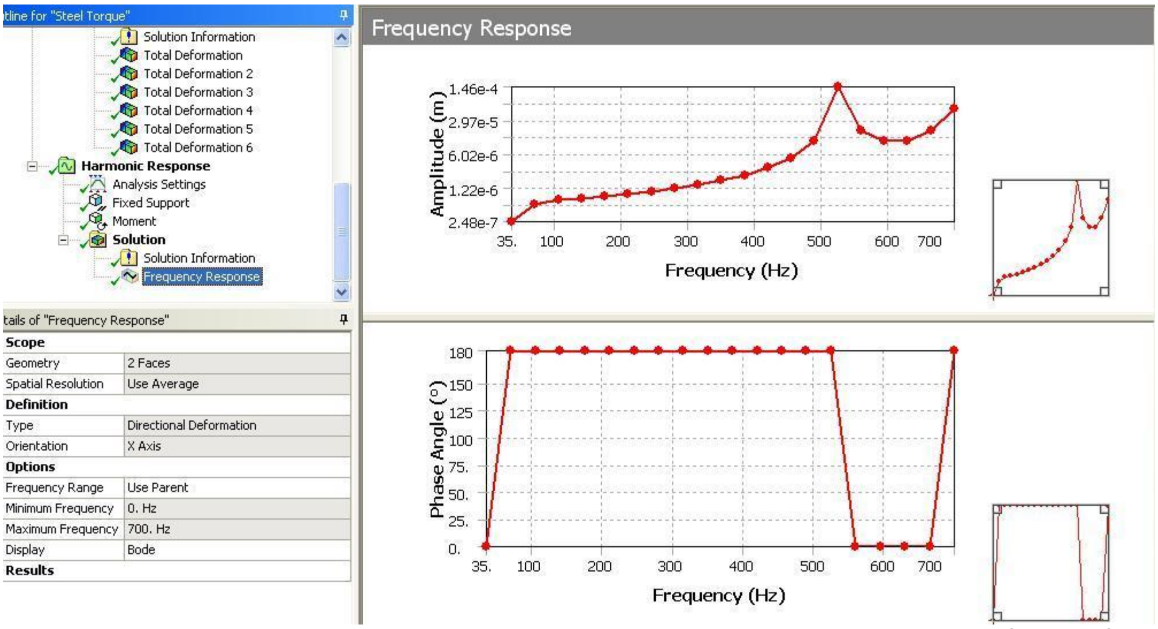
**Ply Orientation : $[0/30]_{8\,S}$**




Frequency Response

Deformation




## RESULTS& ABERVATIONS

It can be seen that Kevlar/Epoxy Composite has shown the maximum reduction in weight followed by Carbon Hybrid, Boron/Epoxy Composite and finally Aluminium Hybrid.

The percentage weight savings of each material is given as follows

Kevlar/Epoxy Composite – 65 % Carbon Hybrid – 57.5 %

Boron/Epoxy Composite – 55.9 % Aluminium Hybrid – 54 %

**Deformation induced in the 5 materials due to torque**

The following graph illustrates the total deformation caused in the assembly due to the application of a torque of 3500 Nm (the rated load for passenger cars).

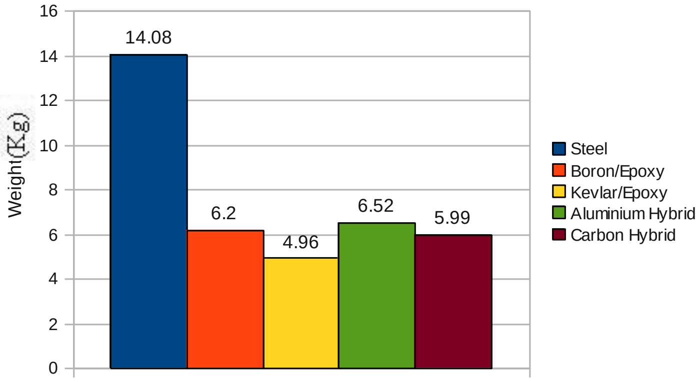
Two Conclusions can be drawn from the following graph

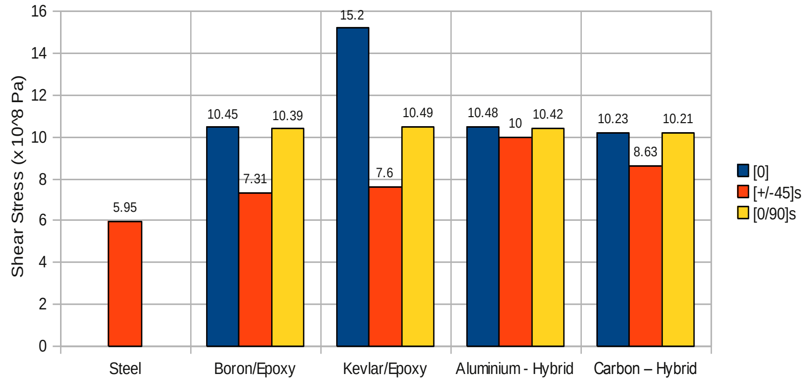
a) It was found that though Steel had the minimum deflection, however it is followed very closely by Boron/Epoxy Composite.

b) The Variation in ply orientations helps us to know that the ply orientation $[+/-45]_{8\ S}$ gives the least amount of deflection when compared to the other two orientations.

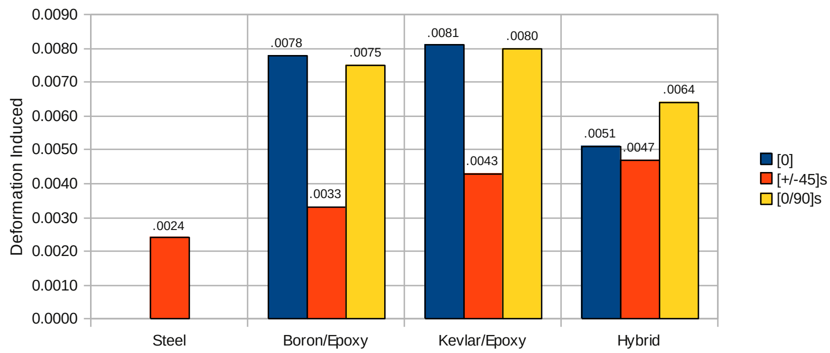
Thus it can be inferred from these observations that throughout the various parameters, analyzed for all the materials, Boron/Epoxy and Kevlar/Epoxy Composites have shown a remarkable similarity in their results. However Kevlar/Epoxy has been found to be 1.24 kg lighter than Boron/Epoxy.

**Reduction in Weight achieved using Composite materials:**






Shear Stress




**Shear Stress induced in the assembly due to the application of 3500 Nm Torque:**

## IV. CONCLUSION

The presented work was aimed at reducing the fuel consumption of the automobiles in particular or any machine, which employs drive shafts, in general. This was achieved by reducing the weight of the drive shaft with the use of composite materials. The Drive shaft of a Toyota Qualis was chosen for determining the dimensions, which were then used for creating a model in CATIA V5R17. The material properties of composites were determined based on Classical Lamination Theory using a C Code. Being a complex assembly of a number of parts, it had to be analyzed in ANSYS 11.0 Workbench. A total of five materials were chosen for the comparative analysis, including steel, which was used for reference. The usage of composite materials has resulted in considerable amount of weight saving in the range of 65% to 54% when compared to conventional steel shaft. Taking into consideration the weight saving, deformation, shear stress induced and resonant frequencies it is evident that Kevlar/Epoxy composite has the most encouraging properties to act as the replacement for steel out of the considered five materials. And the best suitable ply orientation is [+/- 45°].

## REFERENCES

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Authors

1. Thahar Ali Syed Asst.Prof
   Gurunanak Institutions of Technical Campus
   Ibrahim Patnam, Hyderabad.India
2. Adnan Javed, Design Engineer
   Hyundai Motors India Limited
3. Kasala Raju Asst.Prof
   Gurunanak Institutions of Technical Campus
4. Naga Raju Assoc.Prof
   Gurunanak Institutions of Technical Campus