DESIGN, COMPARISON AND ANALYSIS OF A COMPOSITE DRIVE SHAFT FOR AN AUTOMOBILE

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Abstract: Drive shaft is a mechanical instrument which is used in automobiles. Most popularly this drive shaft is known as the propeller shaft, while coming to the construction it was long cylindrical structure consists of thee universal joints. Drive shaft is used to transfer the rotary motion to the differential by using the helical gear box. This rotary motion is used to run the rear wheels. The 3D Model of automobile drive Shaft is done using CREO parametric which enables design automation and product development processes and thereby brings about an optimum design. The conventional drive shafts are made in two pieces for reducing the bending natural frequency, whereas the composite shafts can be made as single-piece shafts, thus reducing the overall weight. The replacement of composite materials (Kevlar, e-glass epoxy) can results in considerable amount of weight reduction if compared to conventional steel shaft. The composite drive shaft made up of high modulus material is designed by using CAD software and tested in ANSYS for optimization of design or material check and providing a best material.

Index Terms: Composite, FEA, Drive shaft.

1. INTRODUCTION

Drive shaft is a mechanical instrument which is used material that has superior properties to those of its in automobiles. Most popularly this drive shaft is known individual constituents. The constituent's areas the propeller shaft, while coming to the construction it combined at a macroscopic level and or not soluble was long cylindrical structure consists of thee universal in each other. The main difference between joints. Drive shaft is used to transfer the rotary motion to composite and an alloy are constituent materials the differential by using the helical gear box. composites, whereas in alloys, constituent materials This drive shaft has wide applications in automobile are soluble in each other and forms a new material world, used in the vehicles like trucks, buses, aero planes.

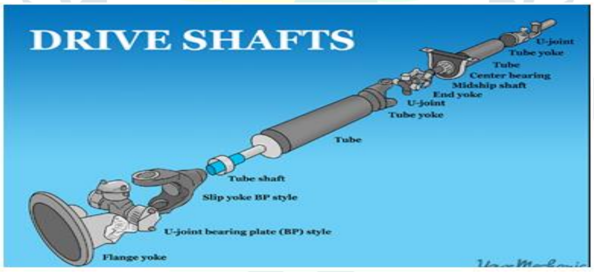

Figure 1: Drive Shafts

A driveshaft is a rotating shaft that transmits drive to wheels. Driveshaft must operate through constantly changing angles between the transmission and axle. High quality steel (SteelSM45) is a common material for construction. Power transmission can be improved through the reduction of inertial mass and light Hook's weight. In the design of metallic shaft, knowing the torque and the allowable shear stress for the material, the size of the shaft's cross section can be determined.

1.2 Types of Drive Shaft:

There are various type of Transmission shaft among them following are important
1. Transmission shaft.
2. Machine shaft.
3. Spindle.
4. Automobile drive shaft.
5. Ship propeller shaft.
6. Helicopter tail rotor shaft.

1.3 Functions of the Drive Shaft:

- First, it must transmit torque from the transmission to the differential gear box.
- During the operation, it is necessary to transmit maximum low-gear torque developed by the engine.

- The drive shaft must also operate through constantly changing angles between the transmission, the differential and the axles. As the rear wheels roll over bumps in the road, the differential and the axle move up and down. This movement changes the angle between the transmission and the differential.
- The length of the drive shaft must also be capable of changing while transmitting torque. Length changes are caused by axle movement due to torque reaction, road deflections, braking load and so on. A slip joint is used to composite for this motion. The slip joint is usually made of an internal and external spline. It islocated on front end of the drive shaft and is 3 Shear strength Ss Mpa 420 connected to the transmission.

II. LITERATURE REVIEW

A.R. Abu Talib, Aidy Ali, Mohamed A. Badie , Nur Azida Che Lah, A.F. Golestaneh investigated about hybrid, carbon/glass fiber-reinforced, epoxy composite automotive drive shaft. They found that changing carbon fibers winding angle from 0^0 to 90^0, the loss in the natural frequency of the shaft is 44.5%, while, shifting from the best to the worst stacking sequence, the drive shaft causes a loss of 46.07% in its buckling strength. The best fiber orientation angle for maximum buckling strength is 90^0. Natural frequency is maximum at 0^0 and decreases as the fiber angle shifts towards 90^0 [1].

Shaw D, Simitses DJ, Sheinman I investigated about Imperfection sensitivity of laminated cylindrical shells in torsion and axial compression. They found that the linear analysis is considered satisfactory in comparison with nonlinear analysis due to the fact that cylindrical shells under torsion are less sensitive to imperfections [2].

H.B.H. Gubran investigated about Dynamics of hybrid shafts and he found that Depending on E1/q ratio for metals and fiber angle for composites, the natural frequencies of hybrid shafts can be optimally placed [3].

Ercan Sevkat, Hikmet Tumer, investigated about Residual torsional properties of composite shafts subjected to impact Loadings. They found that the Carbon reinforced composite shaft had the highest; glass reinforced composite had the lowest resistance to impact. Resistance of hybrid composite shafts was between that of glass and carbon [4].

H. Bayrakceken, S. Tasgetiren, I. Yavuz, investigated about two cases of failure in the power transmission system on vehicles: A universal joint yoke and a drive shaft, they concluded that failures are occurred as a result of fatigue process [5].

III. METHODOLOGY:

- Modeling and analysis of 3-Dimensional models of the drive shaft were carried out using CREO and analysis is carried out using Ansys software structural analysis of composite drive shaft and steel drive shaft are carried out. The results are compared with steel shaft to validate our project.
- Study of cause of failures in drive shaft
- Selection of composite materials
- Preparation of CAD model
- Analysis the CAD model with existing material with Ansys
- Analysis of drive shaft by using different composite materials
- The results are compared with validate our project

Table1: Dimensions' of drive shaft

S. No.	Description	Notations	Value
1	Outer diameter	D	70mm
2	Inner diameter	d	56mm
3	Thickness of the shaft	t	7mm
4	Length of the shaft	L	1800mm
5	Radius of the shaft	r	31.5mm

Table2: Various Material Properties

Properties	Steel	E-glass	Kevlar	Born
Density (Kg/cm^3)	78.50	1950	1440	2450
Young's modulus (Gpa)	207	52.36	152	420
Poisson's Ratio	0.3	0.24	0.35	0.2

Table 3: Formulas of the Various materials

Formulas	Kevlar	E-glass	Born
Critical Stress (N/mm$^{2)}$	4139.55	1351.66	10692
Torsional Bucking Capacity (KN-m)	180.655	58.988	466.648
Mass per unit length of shaft (kg/m)	2.29	3.102	3.897
Natural Frequency (Hz)	66.32	52.54	132.76

Comparison of Stainless Steel with Composite Materials:

Table 4: Properties of the Various materials

Property	Stainless Steel	Composite Materials
Specific Strength	Low	High
Specific modulus	Low	High
Weight	High	Low
Cost	High	Low
Corrosion	High	Low
Damping Capacity	Medium	High

IV. INTRODUCTION TO FEA

Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering.

Finite Element Analysis of Drive Shaft using Ansys Workbench

The model of chassis is saved in IGES format which can be directly imported into ANSYS workbench. The imported model for analysis in ANSYS workbench is shown Fig

Imported model

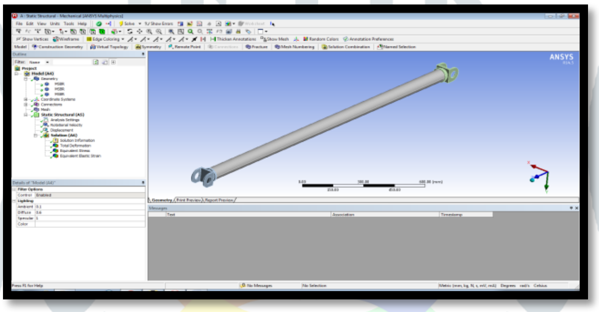

Figure 4: Imported model

Meshing and Boundary Conditions

The meshing is done on the model with 10075 number of nodes and 2393 numbers of tetrahedral elements.

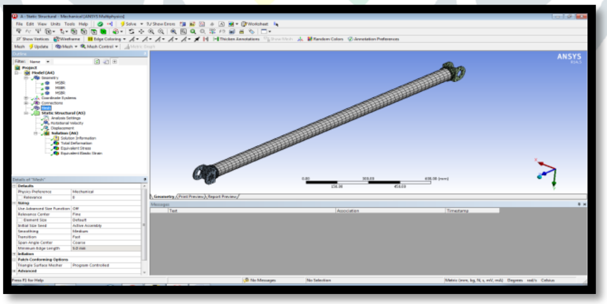

Figure 5: meshed model

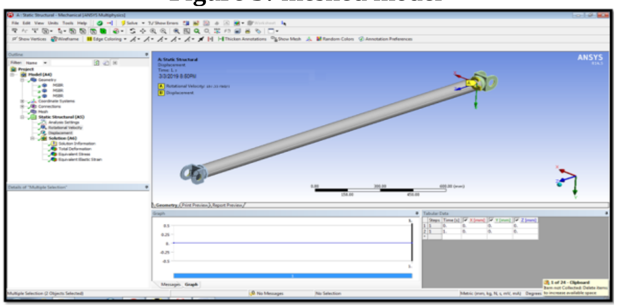

Figure 6: Boundary condition

Material: steel
Total deformation

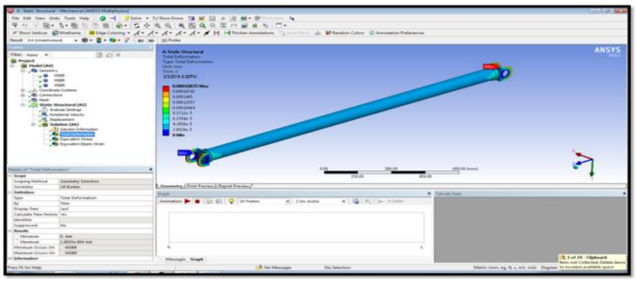

Figure 7: Deformation Analysis

According to the counter plot, the maximum deformation at fixed yoke because of to the fix the holes and the minimum deformation at propeller shaft.
The maximum deformation is 0.0001185mm and minimum deformation is 2.0928e-5.

Stress

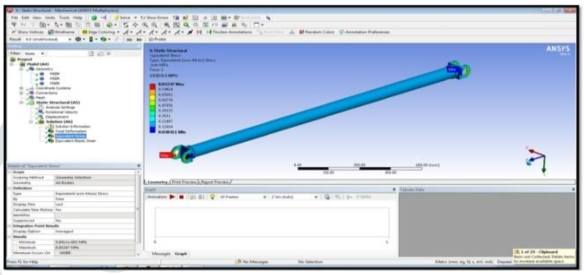

Figure 8 : Stress Analysis

According to the counter plot, the maximum stress at fixed yoke because of to applied rotational speed on propeller shaft and the minimum stress at yoke.
The maximum stress is 0.83247N/mm^2 and minimum stress is 0038421 N/mm^2 .

Strain

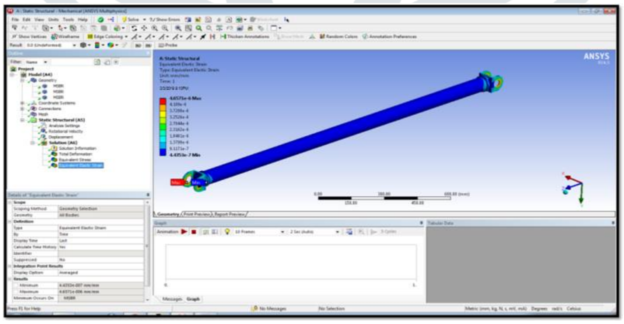

Figure 9 : Strain Analysis

According to the counter plot, the maximum strain at fixed yoke because of to applied rotational speed on propeller shaft and the minimum strain at yoke.
The maximum strain is 4.6751e-6 and minimum strain is 4.4353e-7.

Safety factor

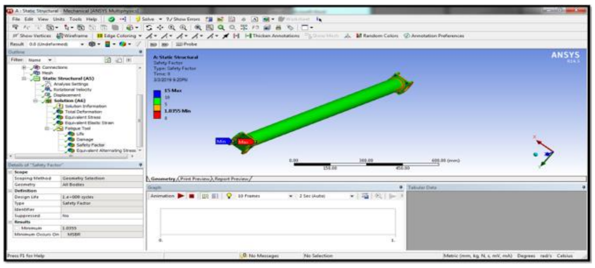

Figure 10: Factor of Safety

According to the counter plot, the maximum safety factor at fixed yoke because of to applied rotational speed on propeller shaft and the minimum safety factor at yoke holes.
The maximum safety factor is 15 and minimum strain is 1.0355.

Table 3. Static Analysis Results Table

Material	Deformation(mm)	Stress (N/mm^2)	Strain	Factor of Safety	
				Min	Max
Steel	0.0001835	0.83247	4.6571e-6	1.0355	15
Kevlar	4.3062e-5	0.14186	1.0624e-6	6.7641	15
Egalss	0.0019173	0.22475	4.7873e-6	3.8353	15
Boron	3.0376e-5	0.28918	7.6592e-7	2.9808	15

Here, from comparison of steel drive shaft with composite drive shaft as shown in above table, it can be seen that the maximum deformation 0.0001835 mm at steel material and corresponding deformation in Kevlar, E glass and boron are 4.3062e-5 mm, 0.0019173mm,3.0376e-5. Also the von-misses stress in the drive shaft for steel 0.83247 MPa while in Kevlar, E glass and boron the von-misses stresses are 0.14186 MPa, 0.22475 MPa and 0.28918Mpa respectively.

STATIC ANALYSIS PLOTS

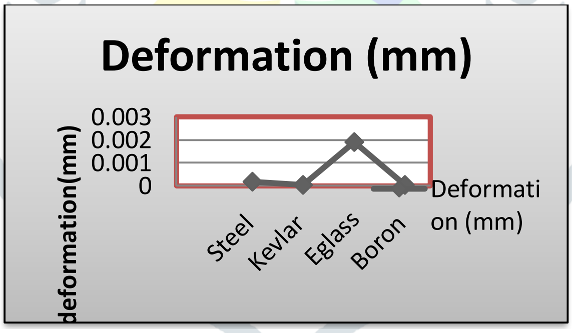

Figure 11: Deformation

According to plot the maximum deformation of drive shaft material E glass and minimum deformation at drive shaft Material Kevlar.

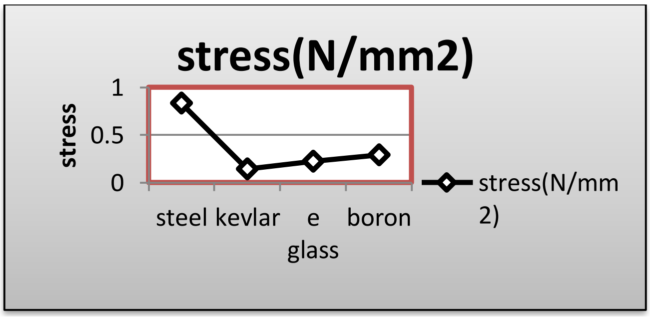

Figure 12: Stress

According to plot the maximum stress of drive shaft material steel and minimum stress of drive shaft Material Kevlar.

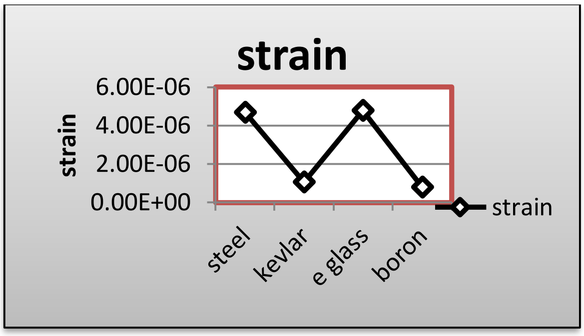

Figure 13 :Strain

According to plot the maximum strain of drive shaft material steel and minimum strain of drive shaft Material Kevlar.

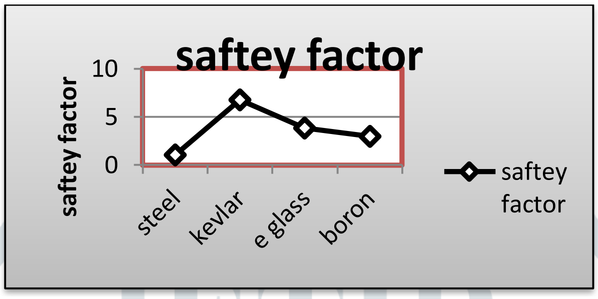

Figure 14 :Factor of Safety

According to plot the maximum safety factor of drive shaft material kevlar and minimum safety of drive shaft Material steel.

MODAL ANALYSIS OF DRIVE SHAFT
MATERIAL –E-GLASS
Total deformation 1

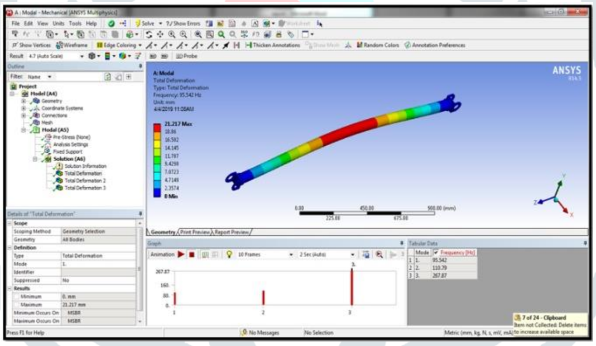

Figure 15 : Deformation Level 1

According to the contour plot, the maximum deformation at propeller shaft because of to fixed the yokes.
The maximum deformation is 21.217 mm at frequency 95.542Hz.

Total deformation 2

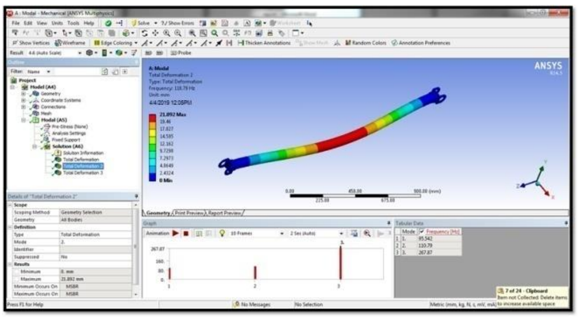

Figure 16 : Deformation Level 2

According to the contour plot, the maximum deformation at propeller shaft because of to fixed the yokes.
The maximum deformation is 21.892 mm at frequency 110.79Hz.

Total deformation 3

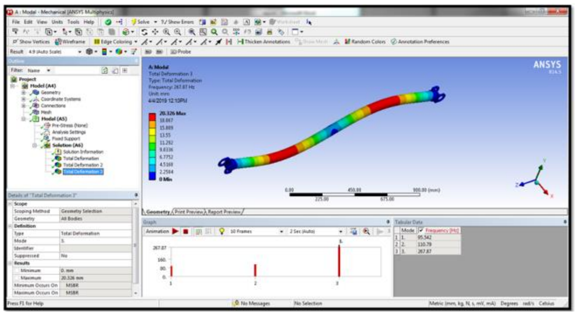

Figure 17 : Deformation Level 3

According to the contour plot, the maximum deformation at propeller shaft because of to fixed the yokes. The maximum deformation is 20.326 mm at frequency 267.87Hz.

Table 4. Modal Analysis Results Table

Material	Mode 1	Frequency (Hz)	Mode 2	Frequency (Hz)	Mode 3	Frequency (Hz)
Steel	10.659	93.885	11.002	109	10.213	262.95
Kevlar	24.899	190.27	25.706	220.97	23.853	532.22
E Glass	21.217	95.142	21.892	110.79	20.326	267.87
Boron	19.072	243.25	19.673	281.78	18.268	682.29

MODAL ANALYSIS PLOTS

Figure 18

According to the plot, the maximum deformation at Kevlar material and minimum deformation at steel.

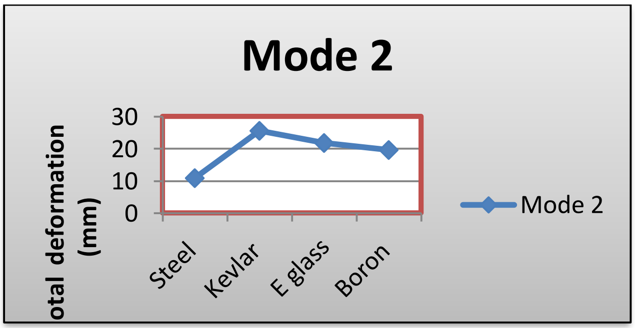

Figure 19

According to the plot, the maximum deformation at Kevlar material and minimum deformation at steel.

Figure 20

According to the plot, the maximum deformation at Kevlar material and minimum deformation at steel.

Comparison plots

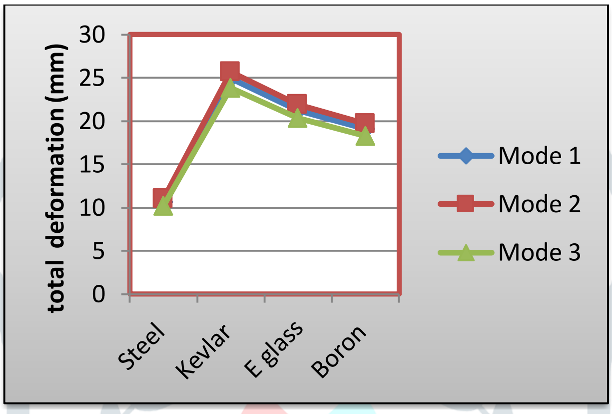

Figure 21

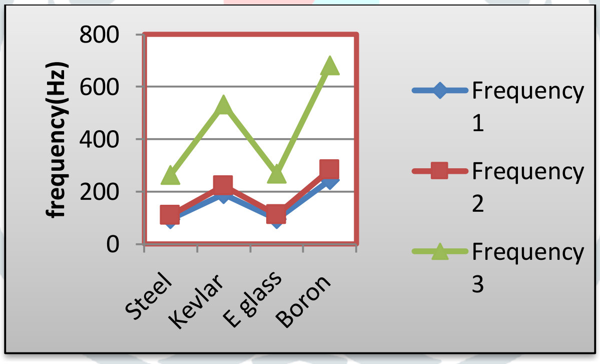

Figure 22

BUCKLING ANALYSIS OF DRIVE SHAFT
MATERIAL –BORON
Total deformation 1

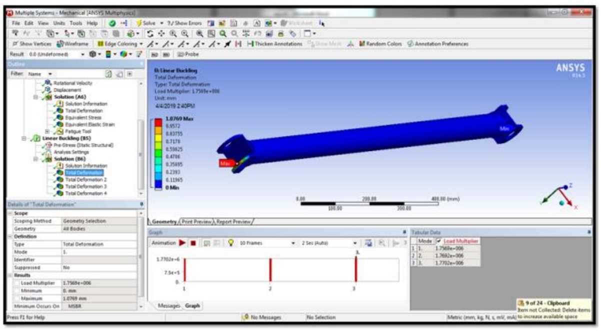

Figure 23 : Total Deformation level 1

According to the contour plot, the maximum deformation at fixed yokes because of to fixed the yokes and minimum deformation at propeller shaft.
The maximum deformation is 1.0769mm at load multiplier1.756e+06.

Total deformation 2

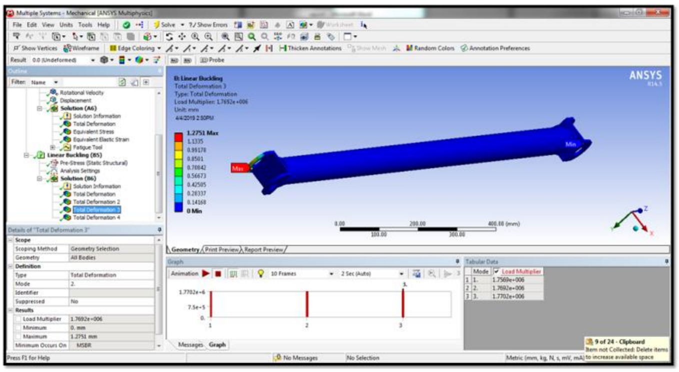

Figure 24: Total Deformation level 2

According to the contour plot, the maximum deformation at fixed yokes because of to fixed the yokes and minimum deformation at propeller shaft.
The maximum deformation is 1.2751 mm at load multiplier1.7692e+06.

Total deformation 3

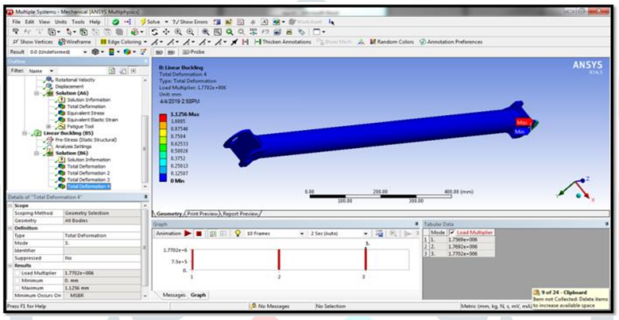

Figure 25 : Total Deformation level 3

According to the contour plot, the maximum deformation at fixed yokes because of to fixed the yokes and minimum deformation at propeller shaft.
The maximum deformation is 1.1256 mm at load multiplier1.7702e+06.

Table 4. Buckling Analysis Results Table

Material	Mode 1	Load Multiplier	Mode 2	Load Multiplier	Mode 3	Load Multiplier
Steel	1.0747	2.6207e+05	1.0735	2.633e+05	1.2295	2.6439e+05
Kevlar	1.0752	1.054e+06	1.0699	1.0617e+06	1.1639	1.649e+06
E Glass	1.0758	2.6838e+06	1.1012	2.6863e+06	1.086	2.698e+06
Boron	1.0769	1.7569e+06	1.2751	1.76692e+06	1.1250	1.7702e+06

BUCKLING ANALYSIS PLOTS

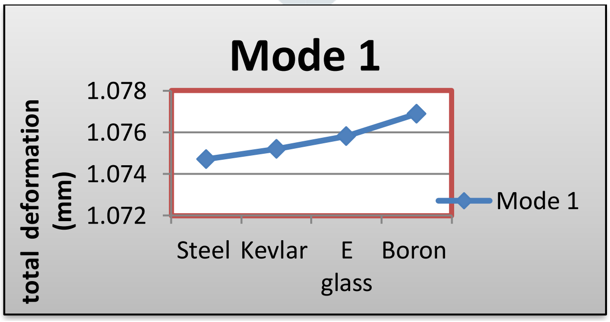

Figure 26

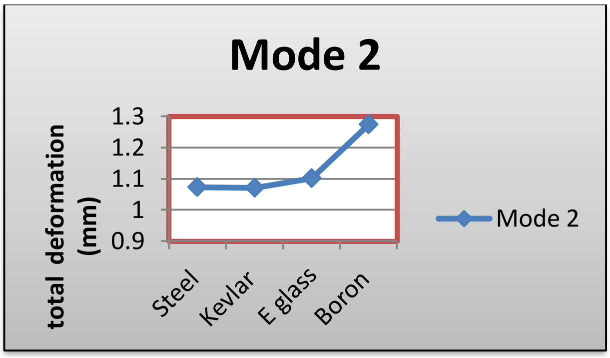

Figure 27

Figure 28

V. CONCLUSION

Here, from static analysis results we compared steel drive shaft with composite drive shaft as shown in above table, it can be seen that the maximum deformation 0.0001835 mm at steel material and corresponding deformation in Kevlar, E glass and boron are 4.3062e-5 mm, 0.0019173mm,3.0376e-5. Also the von-misses stress in the drive shaft for steel 0.83247 MPa while in Kevlar, E glass and boron the von-misses stresses are 0.14186 MPa, 0.22475 MPa and 0.28918Mpa respectively.

Here, from modal analysis results when we compared steel drive shaft with composite drive shaft as shown in above table, it can be seen that the maximum deformation 24.899mm at Kevlar material and corresponding deformation in Steel, E glass and boron are 10.69 mm, 21.217mm and 19.072mm respectively.

Here, from buckling analysis results when we compared steel drive shaft with composite drive shaft as shown in above table, it can be seen that the maximum deformation at modeshape3 1.1639mm at Kevlar material and corresponding deformation in Steel, E glass and boron are 1.2295 mm, 1.086mm and 1.1250mm respectively.

So it can be concluded the Kevlar composite material is the better material for drive shaft.

REFERENCES

[1] M.A. Badie, A. Mahdi, A. M. S. Hamouda. An investigation into hybrid carbon/glass fiber reinforced epoxy composite automotive drive shaft .*Mater. & Des.*, Vol.32, 2011, pp. 1485-1500

[2] A.R. Abu Talib , Aidy Ali , Mohamed A. Badie , Nur Azida Che Lah ,A.F. Golestaneh Developing a hybrid, carbon/glass fiber-reinforced, epoxy composite automotive drive shaft ,Material and Design ,volume 31,2010,pp 514 - 521.

[3] Shaw D, Simitses DJ, Sheinman I. Imperfection sensitivity of laminated cylindrical shells in torsion and axial compression. Compos Struct 1985;4(3)pp : 35–60.

[4] H.B.H. Gubran,Dynamics of hybrid shafts,Mechanics Research commuication,volume - 32, 2005,pp - 368 -374.

[5] Ercan Sevkat ,Hikmet Tumer, Residual torsional properties of composite shafts subjected to impact Loadings,Materials and design,volume - 51,2013,pp - 956-967.

[6] H. Bayrakceken , S. Tasgetiren, _I. Yavuz, Two cases of failure in thepower transmission system on vehicles: A universal joint yoke and a drive shaft,volume - 14,2007,pp 716-724.