Nat. Volatiles & Essent. Oils, 2021; 8(5): 10368-10382

Optimization of Driveshaft material for Light Commercial Vehicle (Automobile)

[1]Lemma Eticha Feyye, [2]Shimelis Mekuria Edo, [3]Tamana Dabasa Badasa

[1]Lecturer in Dept. of Mechanical Engineering, Ambo University Ambo, Ethiopia

[2] Lecturer in Dept. of Mechanical Engineering, Assosa University, Assosa, Ethiopia

[3]Lecturer in Dept. of Mechanical Engineering, Dire Dawa University, Assosa, Ethiopia

Abstract

This paper examines the layout and evaluation of the drive shaft, which transmits energy from the engine to the differential tools of rear-wheel drive Automobiles. Replacing composite with the aid of using metal systems has many advantages due to the fact stiffness and energy of composite materials. This study's paintings offer the alternative of a two-piece metal drive shaft with a single-piece excessive energy carbon/epoxy and excessive modulus carbon/epoxy composite drive shaft for vehicle application. Carbon/epoxy composite material are used to reduce the stock cost, maintenance, and component complexity and enormous saving in weight. The load of the steel shaft is approximately 94N and the load of the carbon/epoxy composite shaft is 19.787N. Using composite material saves up to 79% weight of drive shaft. Evaluation of stress, strain deformation via way of means using ANSYS15 software. Finally while the hole shaft thickness growth from 3.32 mm to 4.32mm, maximum shear stresses are barely grow.

Keywords: Maximum shear stress, weight saving, analysis of stress, strain by Ansys.

Introduction :

The driveshafts are utilized in car, plane, and aerospace applications. The car enterprise is abusing composite material era for structural segment constructing if you want to advantage the discount of overall weight without affecting car excellence and consistency. Driveshaft ought to perform through frequently moving angles among the transmission and axle. It needs to offer a suitable electric power to axles [8]. The force shaft ought to supply a smooth, non-stop flow of energy to the axles. Differential gearbox can get its rotational force from the transmission through Driveshaft. The drive shaft additionally is executed of rotating at a completely the quickest speeds critical through the car [2].

When the length of a metal drive shaft is going past 1500 mm, Characteristics of composite materials can range relying on the sort of the carried-out material, amount, and fiber placement angle. The preference of material relies upon the service lifetime, product shape, calculation of exceptional functions of composite materials, etc. In a few cases, the exceptional results may be completed by the use of a mixture of composite and conventional metallic substances.

This paper research shafts received through a mixture of aluminum and distinct composite materials– carbon fibers/epoxy resin, glass fibers/epoxy resin, and ramie fibers/epoxy resin. The measurement of the driveshaft has to additionally be able to shift a moving torque. Dimension modifications are produced through axle motion because of torque response, street bends, decelerating masses. The slip joint which product of an inner and outside spline is used to compensate for this motion. It is positioned at the front stop of the driveshaft and is attached to the transmission [13].

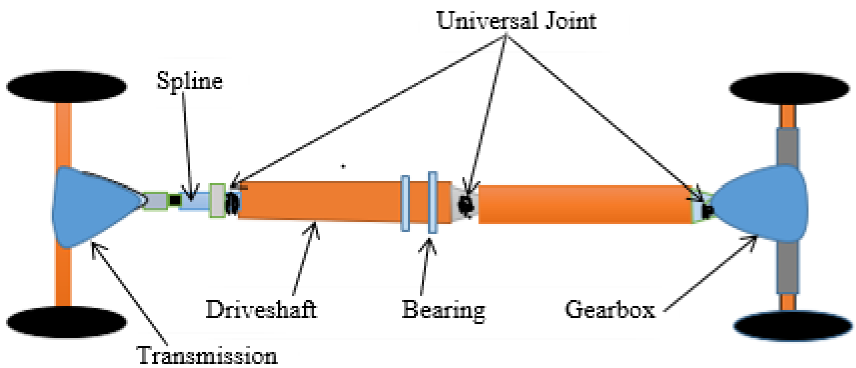


Fig. 1 Conventional Two-Piece Drive Shaft

As dynamic load is appearing at the driveshaft, the natural frequency could be one of the vital elements for design; therefore dividing the driveshaft into portions the usage of an extra widespread joint at a Centre of the shaft will increase its essential natural frequency [12]. This work offers the alternative of traditional piece metal driveshaft to single-piece drive shafts the usage of carbon/epoxy reinforcing fibers.

1. Literature Review :

The theoretical information of composite materials and composite shape is significantly reviewed [5]. The Spicer U-Joint Division of Dana Corporation advanced the primary composite propeller shaft in 1985 for the Ford Econoline van models. The General Motors pickup trucks, which followed the Spicer product have loved a call for three instances that of projected income in its first year [3, 4]. In brief defined, car enterprises are used a software to fabricate composite Leaf spring. On the other hand as structural factor studied, composite polymer Matrix developed in using software [8]. The sizeable involved at the part of each helicopter and vehicle industries with inside the improvement of light-weight drive shafts [9]. The process for coming across the elastic modulus of anisotropic plastic-covered composites is clarified about the anisotropic power of composites [11].

2.1 Torsional Buckling :

The first evaluation of buckling of thin-walled tubes beneath neath torsion was made, however, his evaluation did now no longer trust his experimental data. However, all effects of those studies papers have been restricted to isotropic material. As some distance as orthotropic substances is concerned as well as fashionable theories of orthotropic shells have been evolved and analyzed [14]. The steadiness conduct of rotating composite shafts beneath neath axial disbursed load. A theoretical have a look at becoming on hand for controlling the buckling torque of hole shaft with layers of randomly laminated composite substances by numerous thin-shell theories measured the torsional buckling masses of graphite/epoxy shafts, which have been in desirable settlement with theoretical estimates primarily based totally on a customary shell idea with elastic coupling results and transverse shearing deformation [15].

2.2 Composite material :

Composite materials are a multiple joint materials that create a superior property of divided elements. Those materials are insoluble separately because they are joined in microscopic level. The particular composite needs a reinforcement at all direction to have equal size. The particulate substance are prepared as sphere or plate shape. It also have regular or irregular geometry. Particulate composites are weaker and has less stiffness compared to continuous composites. The aspect ratio of continuous fiber is longer when compared to discontinuous fiber. Composite of continuous fiber has normal orientation but for discontinuous fiber the orientation is random [6].

2.3 Fiber :

Fibers are the primary constituent in a fiber-strengthened composite material which occupy the biggest quantity in a composite laminate and share the principle load performing on a composite structure. Proper choice of fibers may be very crucial as it affects the characteristics of a composite laminate consisting of precise gravity, Tensile strength and modulus, Compressive energy and modulus, Fatigue strength and fatigue failure mechanisms, Electric and thermal conductivities[10].

2.4 Matrix :

In a composite fabric, the fibers are surrounded via way of means of a skinny layer of matrix material that holds fibers in preferred orientation and distributes and carried out the load on all fibers. The matrix can perform a fantastic function in locating the ecological balance of the composite materials in addition to mechanical houses consisting of durability and shear strength. The matrix has to additionally separate the fibers from different in order that they may act as single bodies. The matrix has to guard the reinforcing fibers from damage.

2.5 Weight reduction :

Optimum Design and evaluation of a composite Driveshaft for a vehicle via way of means of the use of a generic set of rules and Ansys. This was studied for the goal of weight minimization of the shaft that is subjected to natural frequency and torque [1]. The weight financial savings of the E – Glass/ Epoxy, High Strength Carbon/ Epoxy, and High Modulus Carbon/ Epoxy shafts had been the same to 48.36%, 86.90%, and 86.9% weight of shaft material respectively. In this look at there may be compression of among Aramid (Kevlar) boron, silicon carbide, silicon nitrates, and alumina fibers with composite material [9].

2.6 Design and Optimization of Drive shaft :

This examines Material optimization and weight loss of drive shaft the use of composite material. The utilization of composite materials has ended in a large amount of weight saving withinside the variety of 81% to 72% while in comparison to standard metallic force shaft. This becomes completed via way of means of decreasing the mass of the force shaft via way of means of composite materials. This additionally permits using a single drive shaft (in place of a piece drive shaft) for transmission of energy to the differential components of the assembler. Using the Bernoulli-Euler beam concept and Timoshenko's beam concept Natural frequency are in comparison. The frequency calculated via way of means of the use of the Bernoulli-Euler beam concept is excessive because it neglects rotary inertia and transverse shear [9].

2.7 Failure Analysis Drive Shaft :

Drive shafts can use as a power transmitter in automobile instead of chain-drives because it has Long service time. Torsional and bending stress are subjected to drive shaft during operation. fatigue and fractural failures are the result these two stresses. The main Causes of drive shaft failure are design and manufacturing, and operational problem [10]. operating angles of outer joint of drive shaft is 40 degrees while its Inner joint is only 10 to 20 degrees. This makes drive shaft failure rate maximum at its outer Joints [11]. Boots are used to protect the joints of Drive shafts. Abrasion of balls is a result of Dust and Dirt particle accumulated into Boots and Grease from rough surface of the road. The percentages of Drive shaft failures caused by problems in CV joints, negligence in installation, and wear of parts are 80%,8%, and 4% respectively [12].

Design of carbon/epoxy composites Drive Shaft :

The goal design of the carbon/epoxy composite driveshaft is the minimization of weight, so the goal feature of the hassle is given as follows. Based on the benefits mentioned earlier, High Modulus Carbon/Epoxy materials are decided on for the composite driveshaft. Table 1 indicates the property of the High Modulus Carbon/Epoxy and E-Glass/epoxy composite material used for the drive shafts [8].

Table 1. Mechanical properties of carbon/epoxy composite material

S. No	Mechanical property	symbol	High modulus Carbon/Epoxy
1	Longitudinal modulus	E_1	190 Gpa
2	Transverse modulus	E_2	7.7 Gpa
3	Shear modulus	G_{12}	4.2 Gpa
4	Poisson's Ratio	Y	0.3
5	Density	P	1600 Kg/m^3
6	Longitudinal Tensile Strength	S_{t1}	870 Mpa
7	Transverse Tensile Strength	S_{t2}	540 Mpa
8	Shear strength	S_s	30 Mpa
9	Young's modulus	E	210 Gpa

Table 2 Specification of drive Shaft

S. No	Name	Symbol	Value
1	Length of shaft	L	1250 mm
2	Outer diameter of shaft	d_o	100 mm
3	Inner diameter of shaft	d_i	93.36 mm
4	Thickness of shaft	t	3.32 mm
5	Ultimate torque	T	3500 Nm

6	Max-speed of drive shaft	N	6500 Rpm

Design of mass for carbon/epoxy composite material drive shaft.

$m = \rho AL = \rho * \pi * L \frac{(do^2 - di^2)}{4}$ (1)

$= 1600 * \pi * 1.25 \frac{(0.1^2 - 0.09336^2)}{4}$

=2.017 kg

Where do = outer diameter (m)

di = inner diameter (m)

L = length of the drive shaft (m)

ρ = density of carbon epoxy composite material (kg/m^3)

A = cross sectional areas of drive shaft (m^2)

m = 2.017 Kg

w = mg

= 19.787 N

Where m = mass of carbon/epoxy composite material (kg)

g = forces of Gravity (m/s^2)

w = weight of carbon/epoxy (N)

3.1 Maximum shear stress of Driveshaft

$\tau_{max} = \frac{T}{2\pi r_m^2 t}$ (2)

Where r_m is the mean radius of the Shaft?

τ_{max} =The maximum allowable shear stress of the shaft

T =Torque Transmission Capacity of carbon/epoxy composite Drive Shaft

The mean radius of the shaft will be.

$r_m = \frac{r_o + r_i}{2}$ (3)

$r_m = \frac{50+46.68}{2}$ = 48.34 mm

Therefore, putting this value in the shear stress equation

$\tau_{max} = \frac{T}{2\pi r_m^2 t}$ (4)

$\tau_{max} = \frac{3500}{2\pi (48.34)^2 * 3.32}$

= 0.0718 Mpa

The torsional strength of the shaft is 0.0718Mpa. SM45C steel changed into decided-on for drive shaft material due to the fact it's far broadly used for the layout of the traditional metal shaft. The properties of SM45C steel are [7].

Table 3. Material property of steel (SM45C)

S. No	Mechanical property	Symbol	Value
1	Young's modulus	E	207 GPa
2	Shear modulus	G	80 GPa
3	Poisons ratio	Y	0.3
4	Density	P	7600 Kg/m^3
5	Yield strength	S_Y	370 Mpa
6	Shear strength	S_s	257 Mpa

Design of mass for Steel (SM45C) material of driveshaft

$m = \rho AL = \rho \times \pi \times L \frac{(do^2 - di^2)}{4}$

$= 7600 \times \pi \times 1.25 \frac{(0.1^2 - 0.09336^2)}{4} = \underline{9.58}$ kg

W = mg

Where w = weight of steel shaft

m = mass of the steel and

g = Gravity acceleration take as 9.81 m/s^2

w = 9.58 kg * 9.81(m/s^2 = $\underline{94}$ N

3.2 Torsional buckling capacity of driveshaft

An orthographic skinny hole cylinder will buckle torsional. Buckling of the shaft arises whilst implemented torque is more than essential torsional buckling load. Finally, the implemented torque needs to be much less than essential buckling torque to keep away from buckling. [4]

A shaft is considered as a long shaft.

If $\frac{1}{\sqrt{(1-\vartheta^2)}} \frac{L^2\, t}{(2r)^3} > 5.6$ (5)

$= \frac{1}{\sqrt{(1-0.3^2)}} \frac{1.25^2 \times 0.00332}{(2 \times 0.04834)^3} > 5.5$

=6.03> 5.5 It is called as long shaft otherwise short and medium shaft [31]

The critical stresses of shaft is given by,

$\tau_{cr} = \frac{E}{\sqrt[3]{2}\ (1-v^2)^{3/4}} \left(\frac{t}{r}\right)^{3/2}$ (6)

$= \frac{207}{\sqrt[3]{2(1-0.3^2)^{3/4}}} \left(\frac{0.00332}{0.04834}\right)^{3/2}$

= 0.34685 N-mm^2

Where: - υ = Poisons ratio

E = Young's modulus of steel material

τ_{cr} = critical stress on drive shaft of steel material

For short & medium shaft, the critical stress is given by,

$\tau_{cr} = \frac{4.39E}{(1-v^2)} \sqrt{1 + 0.0257(1-v^2)^{\frac{3}{4}} \frac{L^3}{(rt)^{1.5}}}$ (7)

$\tau_{cr} = \frac{4.39 \times 207}{(1-0.3^2)} \sqrt{1 + 0.0257(1-0.3^2)^{3/4} \frac{1.25^3}{(48.34 \times 3.32)^{1.5}}}$ = 31.356 N mm

torsional buckling and critical stress relations.

$T_b = \tau_{cr} 2\pi r^2$ (8)

T_b = 31.356$\times 2 \times 48.34^2 \times 3.32$ = 486,521.149 N-mm

3.3 Comparison of mass between Steel and carbon/epoxy Composite drive Shafts

Table 4 gives the comparison of mass between steel (SM45C) and Carbon/Epoxy composite drive shaft.

Percentage of weight reduction = $\frac{(\text{weight of steele – weight of carbon/epoxy composite})}{\text{weight of the steel drive shaft}}$x100

W = $\frac{(93.98-19.787)}{93.98} * 100$= 79 %

Table 4. Weight Comparison

Material	Weight (N)	Weight saving (%)
Steel	93.98	-
Carbon/Epoxy	19.787	79%

3.4 Natural frequency applied on a rotating shaft :

Natural frequency of the shaft

$\omega_{en} = n^2 \times \pi^2 \sqrt{\frac{E\ .\ I}{m\ .L^3}}$ (9)

Where n = 1, 2, 3 …

m = mass of the shaft

The shaft moment of inertia

I = $\frac{\pi}{64}(d_o^4 - d_i^4)$ (10)

I = $\frac{\pi}{64}(50^4 - 46.68^4)$= 3.486 x$10^{-8}$ mm^4

Equation 9 & 10 are inserted into equation 10.

3.5 Natural frequency of carbon/epoxy composite material :

$\omega_{en} = n^2\pi^2 \sqrt{\frac{E.(d_o^2 - d_i^2)}{16\ .\ \rho\ .\ L^3}}$ (rad/s) (11)

$\omega_{en} = 1^2 \times \pi^2 \sqrt{\frac{210\ .(0.1^2 - 0.09336^2)}{16\ .1600\ .1.25^3}}$ = 0.008156 rad/s

3.6 Natural frequency of steel SM45C

$\omega_{en} = 1^2 \times \pi^2 \sqrt{\frac{207\ .(0.1^0 - 0.09336^2)}{16\ .\ 7600\ .\ 1.25^3}}$ = 1.5310 rad/s

3.7 Maximum Shear stress

$\tau = \frac{T\,(d_o - d_i)}{2J}$ (12)

$=\frac{3500(100-93.36)}{2x2,357.32}$ = 4.929 Mpa

3.8 Maximum static deflection

$$\delta = \frac{TL^2}{2EI} \qquad (13)$$

$=\frac{3500 \times (1.25)^2}{2 \times 207 \times 3.486 \times 10^{-8}}$ = 3.789e5mm

Table 5. elasticity of composite material

S. No	Mechanical property	symbol	High modulus Carbon/Epoxy
1	Longitudinal modulus	E_1	190 Gpa
2	Transverse modulus	E_2	7.7 Gpa
3	Shear modulus	G_{12}	4.2 Gpa
4	Poisson's Ratio	Υ	0.3

2. Modeling of drive shaft :

The major dimensions of drive shaft considered for present analysis are as following.

Hollow shaft, outer diameter (d_o) = 100 mm

Inner diameter (d_i) = 93.36 mm

Total Length = 1250mm

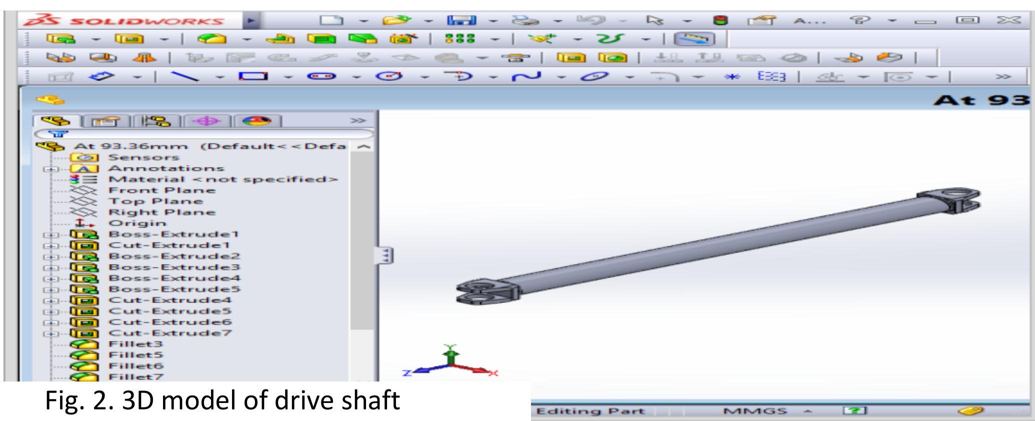
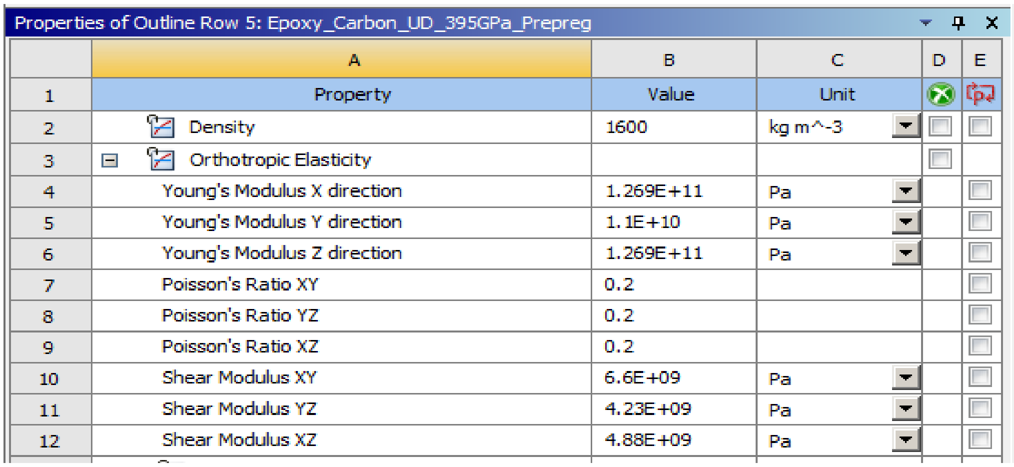


Fig. 2. 3D model of drive shaft

Table 6. Properties of Steel (SM45C) material for drive shaft for analysis by using ansys

Material type	**Steel (SM45C)**
Density	7600 Kg/m^3
Young's modulus	207 Gpa

Poisson's ratio	0.3


Properties of Outline Row 5: Epoxy_Carbon_UD_395GPa_Prepreg

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	1600	kg m^-3		
3	Orthotropic Elasticity				
4	Young's Modulus X direction	1.269E+11	Pa		
5	Young's Modulus Y direction	1.1E+10	Pa		
6	Young's Modulus Z direction	1.269E+11	Pa		
7	Poisson's Ratio XY	0.2			
8	Poisson's Ratio YZ	0.2			
9	Poisson's Ratio XZ	0.2			
10	Shear Modulus XY	6.6E+09	Pa		
11	Shear Modulus YZ	4.23E+09	Pa		
12	Shear Modulus XZ	4.88E+09	Pa		

Fig. 3. Carbon/epoxy composite materials and their properties that were used in this analysis

The most typically used shapes of finite detail are triangular and quadrilateral for 2 Dimensional equation problems and tetrahedral for 3 Dimensional problems. The triangular and tetrahedral facet factors have the benefit of being capable of version very complicated geometries. This meshing length is 5 mm for each metal and carbon/epoxy composite driveshaft.

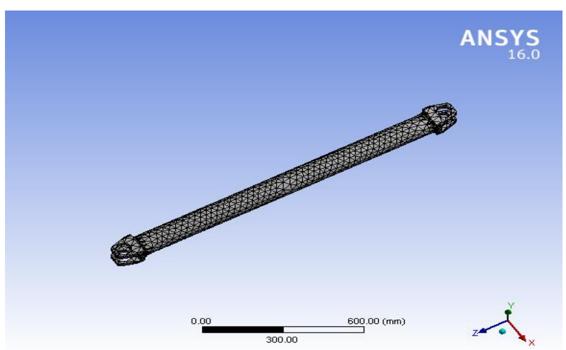


Fig. 4. Driveshaft meshing with rectangular shape of elements

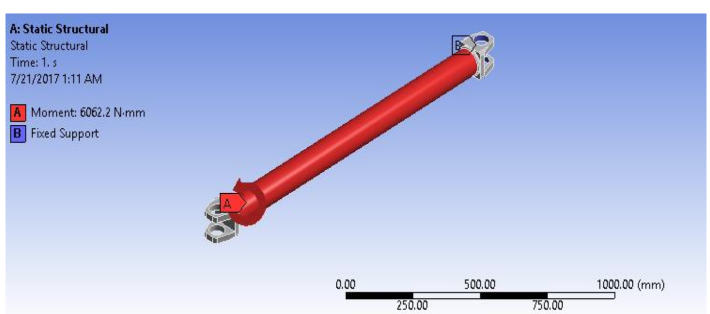


Fig. 5. Finite element model of HS Carbon/Epoxy shaft

For drive shaft shown in Figure 5 one end is fixed and moment is applied at free end.

3. Results and Discussions :

In this research work, the drive shaft version became created via way of means of Solid work software program. Then, the version created via way of means of stable work became imported to ANSYS software program for analysis.

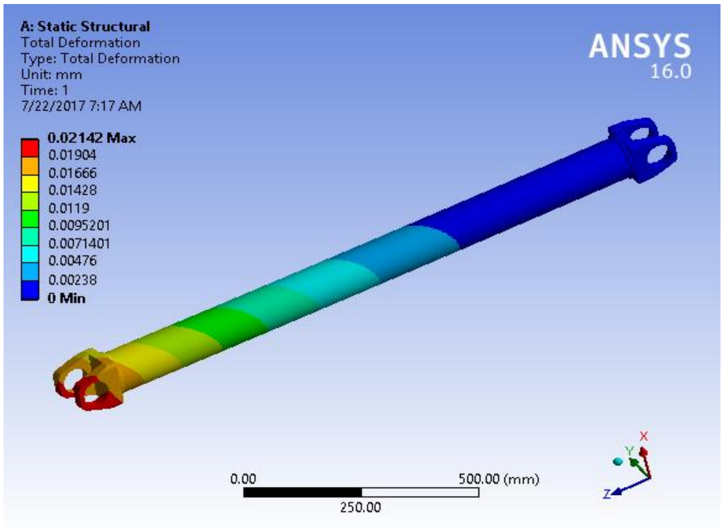


Fig. 6. Deformation at 3.32mm thickness of drive shaft of steel (SM45C)

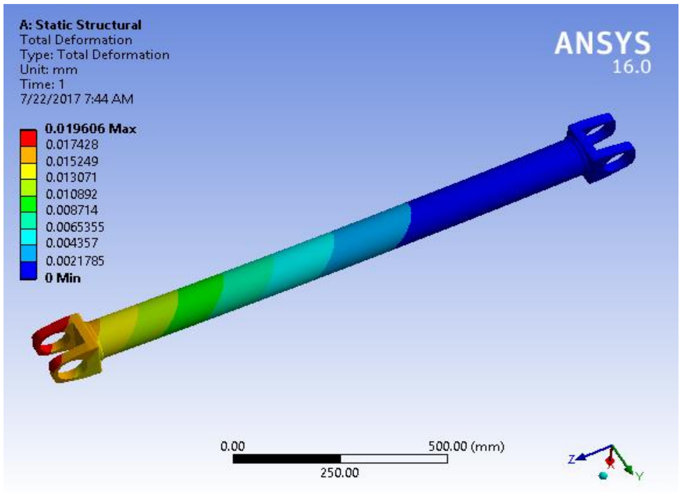


Fig. 7. Deformation at 3.82mm thickness of drive shaft of steel (SM45C)

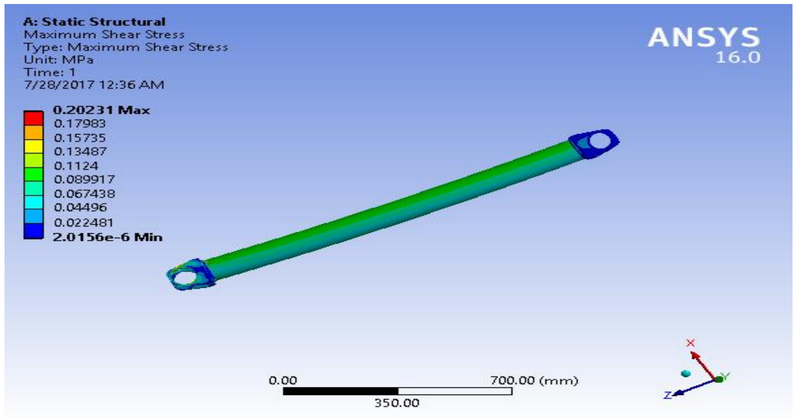


Fig. 8. Maximum shear stress at 4.32 mm thickness of hollow drive shaft for steel SM45C

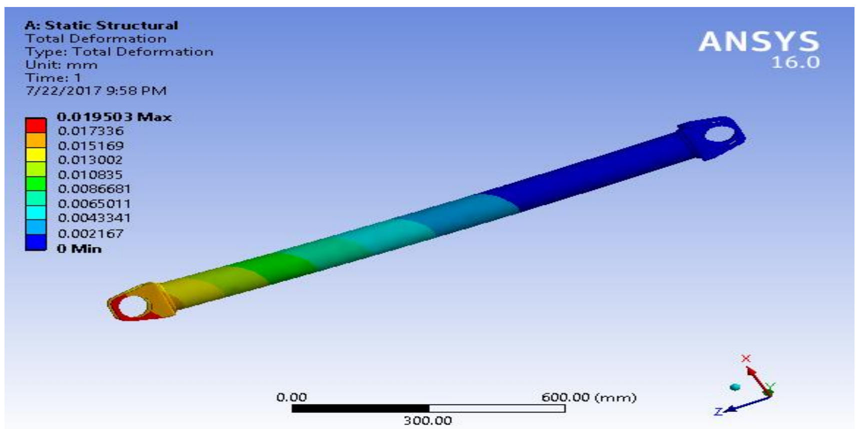


Fig. 9. total deformation 3.82mm thickness of drive shaft of carbon/epoxy

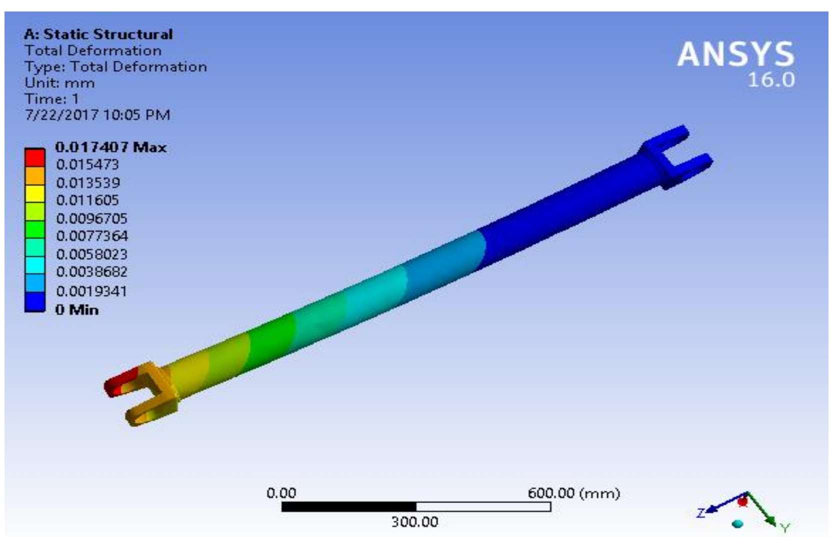


Fig. 10. Total deformation at 4.32mm thickness of the drive shaft

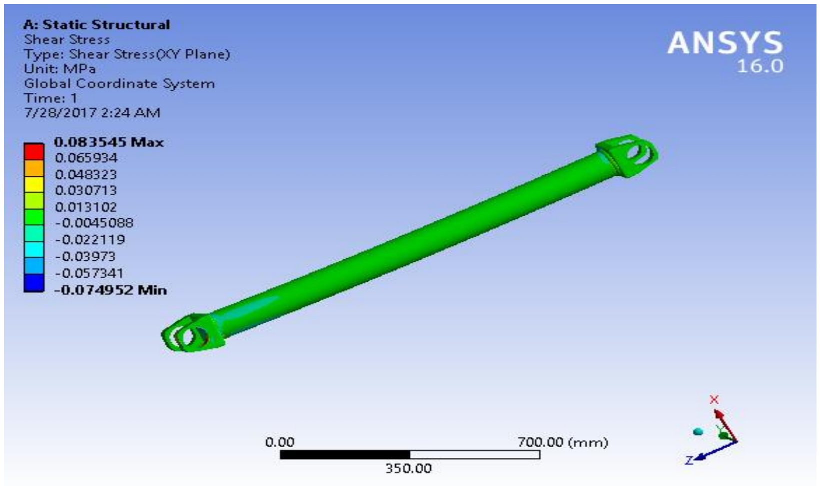


Fig. 11. Shear stress of carbon/epoxy hollow shaft at 4.32mm thickness

Discusssion :

Table 7. Results of total deformation

Total deformation				
S. No	**Hollow shaft thickness**	**For carbon/epoxy**	**For steel (SM45C)**	**Unit**
1	3.32	0.02103	0.02142	(mm)
2	3.82	0.019503	0.019606	(mm)
3	4.32	0.017407	0.017688	(mm)

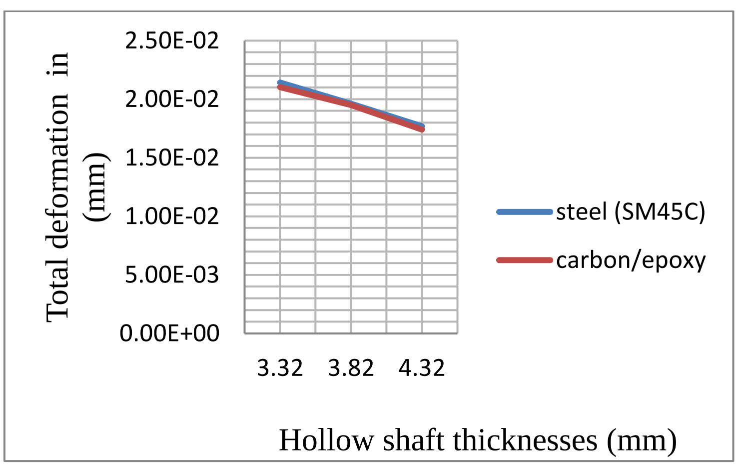


Fig. 12. Total deformation of hollow drive shaft vs to shaft thickness

Generally, when the thickness of hollow shaft increases as total deformation of shaft decreasing. The deformation is 0.02142 and 0.02103 for both steel SM45C and composite material (carbon/epoxy) at the same thickness 3.32mm respectively. As thickness of shaft to increases the load resistance of shaft also increases.

Table 8. Shear stress of Steel (SM45C) and carbon/epoxy composite material (Mpa)

S. No.	Hollow shaft thickness (mm)	Steel (SM45C)	Carbon/epoxy
1	3.32	0.087225	0.09679
2	3.82	0.06314	0.086685
3	4.32	0.059385	0.083545

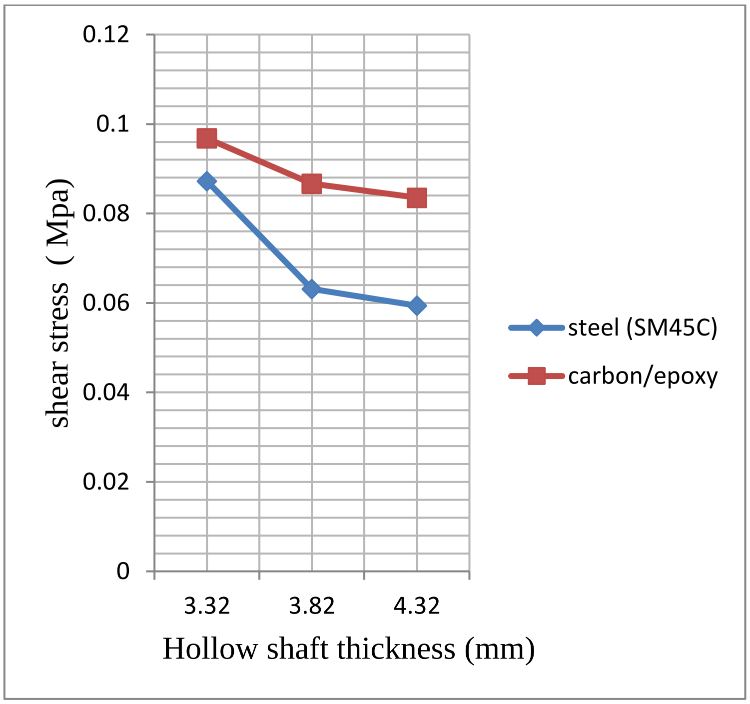


Fig. 13. Distribution of Shear stress on x-y plane

The above graph indicates that the shear pressure distribution on the XY plane is explained. the simulation end result indicates the shear pressure distribution in a single-piece drive shaft. The most to be had shear pressure for each carbon/epoxy composite material and metallic SM45C is 0.083545 max and0.059385max at 4.32mm thickness respectively. From this whilst hole shaft thickness will increase the weight resistance of the shat will increase.

Conclusion :

The High Strength composite material (Carbon / Epoxy) Drive shafts had been designed to update the metal Drive shaft of an automobile. From evaluation, the weight of metal is about 94N and the weights of carbon/epoxy composite are 19.787N. From this, there's weight saving in 79%. Because of this, there's gasoline intake because of weight reduction.

The utilization of composite material has resulted in an inconsiderable quantity of the load saving withinside the variety of 79% whilst as compared to the standard metal drive shaft. The supplied work became additionally aimed to offers with layout and evaluation of drive shaft and changing two-piece metal (SM45C) drive shaft into single-piece of carbon/epoxy composite material. Driveshafts of various diameters are decided on evaluation made from carbon/epoxy composite cloth and metal (SM45C) and the simulation end result indicates whilst the thickness of the drive shaft will increase the weight resistivity is likewise growing. in the end, the hole shafts of 100mm out of doors diameter and 93.36mm internal diameter is the usage of High Strength Carbon/epoxy composite are because of the first-class one. But, Temperature has an impact on composite mechanical properties. Typically, matrix-ruled mechanical properties are lower with growing temperature.

References :

1. D. Dinesh F. Anand Raju, “Optimum Design and Analysis Of A Composite Drive Shaft For An Automobile By Using Genetic Algorithm And Ansys”, Vol. 2, Issue 4, July-August 2012, Pp.1874-1880.
2. Kuran, Pune, “Material optimization and weight reduction of drive shaft using composite material”, Vol-1 Issue-5 2015.
3. Virendra V. Maheta, “Design, Analysis and Optimization in Automobile Drive Shaft”, IJIRST International Journal for Innovative Research in Science & Technology| Volume 1 | Issue 12 |May 2015 ISSN (online): 2349-6010.
4. Shahanawaz Alam, Akshansh Uniyal, Abhinn Bajaj, “Evaluation of structural and vibration characteristic of Composite drive shaft for automobile using FEM”, 5(4): April, 2016.
5. Pandurang V Chopde, “Analysis of Carbon/Epoxy Composite Drive Shaft for Automotive Application”, Vol. 5 Issue 1 January 2015.
6. Chaitanya G Rothea, A.S.Bombatkarb, “Design and Analysis of Composite Material Drive Shaft”, Volume 2, Special Issue 1 MEPCON 2015.
7. V. S. Bhajantri, S. C. Bajantri, A. M. Shindolkar, S. S. Amarapure, “Design and analysis of composite drive shaft”, Volume: 03 Special Issue: 03 | May-2014 | NCRIET-2014.
8. Dai Gil Lee, Hak Sung Kim, Jong Woon Kim, Jin Kook Kim, “Design and manufacture of an automotive hybrid aluminum/composite drive shaft”, Composite Structure 63, 2004.
9. R. P. Kumar Rompicharla, K. Rambabu, “Design and Optimization of Drive Shaft with Composite Materials”, Vol.2, Issue.5, Sep-Oct. 2012 pp-3422-3428.
10. Nimesh A. Patel Pradip M. Patel Prof. A.B.Patel, “FE Analysis of Hollow Propeller Shaft using Steel and Composite Material then Compares It”, IJSRD - International Journal for Scientific Research & Development| Vol. 1, Issue 3, 2013 | ISSN (online): 2321-0613.

11. Satyajit S. Dhore, Hredeya Mishra, “Material optimization and weight reduction of drive shaft using composite material”, Vol-1 Issue-5 2015.
12. M.R. Khoshravan, A. Paykani, “Design of a Composite Drive Shaft and its Coupling for Automotive Application”, Vol. 10, December 2012.
13. Ketan S Patil and V. M. Chidri, “Optimization of a Composite Material Automotive Driveshaft by Using FEM”, Accepted 12 June 2015, Available online 17 June2015, Vol.5, No.3 (June 2015).
14. Sagar Dattatray Jadhav, C. G. Harge, A. P. Shrotri, S. B. Khandagale, “A review on —Design Optimization of composite material Drive Shaft of an automobile”, IJAEST, Volume 5, Number 1.
15. Harshal Bankar, Viraj Shinde, P. Baskar, “Material Optimization and Weight Reduction of Drive Shaft Using Composite Material”, Volume 10, Issue 1 (Nov. - Dec. 2013), PP 39-46.