Weight Optimization and Finite Element Analysis of Drive Shaft for Rear-Wheel Drive Engine by using Composite Material

Sneha K. Jumble[1] Vaishali S. Patil[2] Ganesh M. Bagade[3] Chetan P. Patil[4]
[1,4]Assistant Professor [2,3]Lecturer
[1,2,3,4]Department of Mechanical Engineering
[1,4]STC, SERT, Khamgaon [2,3]STC, SPRT, Khamgaon

Abstract— Drive shaft is the most important component to any power transmission application; automotive drive Shaft is one of this. A drive shaft is a mechanical part that transmits the torque generated by a vehicle's engine into usable motive force to propel the vehicle. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This work deals with the replacement of conventional steel drive shafts with different material such as fiberglass epoxy, composite fiber, and hybrid material. The design parameters were optimized with the objective of minimizing the weight of composite drive shaft. The design optimization also improves the performance of drive shaft. Present work deals with FEA analysis of composite shaft with different composite material. It includes the modeling of shaft in CATIA. The meshing and boundary condition application is carried using Hypermesh; Structural analysis of composite shaft will be carried out using ANSYS. Composite shaft is fabricated and tested to validate with numerical values.

Key words: Composite Material, Conventional Steel Drive Shaft, Rear Axle Wheel Shaft etc

NOMENCLATURE

V	Velocity (m/min)
D	Tire Diameter (m)
Nv	Speed of Vehicle (rpm)
P	Power (J/s)
T	Applied Torque (Nm)
N	Drive shaft rpm
E	Young’s Modulus (GPa)
ν	Poisson’s Ratio
ρ	Density (kg/m^3)
E_1	Young’s Modulus for one layer of Glass Fiber material (GPa)
E_2	Young’s Modulus for two layer of Glass Fiber material (GPa)
E_3	Young’s Modulus for three layer of Glass Fiber material (GPa)

I. INTRODUCTION

The technological advances in engineering design field result in finding the alternate solution for the conventional materials. The design engineers brought to finding the materials which are more reliable than conventional materials. Designers and Researchers are constantly looking for the solutions to provide stronger and enduring materials which will answer the needs of fellow the design engineers. Drive shafts are used in many applications such as power transmission tubing, including cooling towers, pumping sets, aerospace, trucks and automobiles. 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. Now a days there is a heavy requirement for lightweight materials vehicle.

Type of axle used: Axles are divided into three main groups:
1) Semi-floating
2) Three-quarter floating
3) Fully floating.

Semi floating type of drive axle of Bolero car is used for the project purpose. Drive axle and related components are shown in fig. 1.

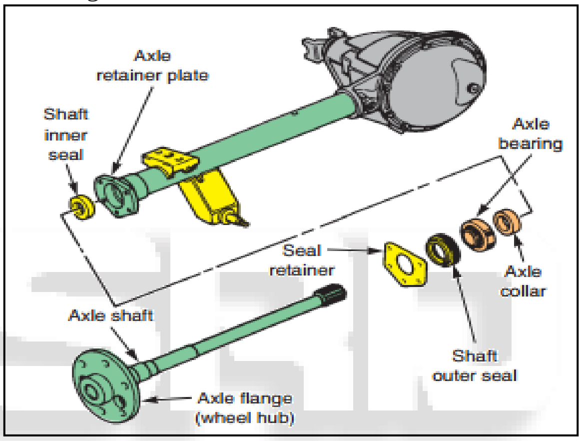

Fig. 1: Drive axle and related component

A. *Basic Concepts of Composite Materials*

Composite materials are basically known as hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a one structural material. The meaning of composite material such as made up of two or more parts. A composite material is one made of the two other materials. The composite material then has the properties of the two materials that have been combined.

Some of the properties that can be improved by forming composite material are as follows
- Strength-fatigue life
- Stiffness-temperature-dependent behavior
- Resist to Corrosion -thermal insulation
- Resist to wear-thermal conductivity
- Attractiveness -acoustical insulation
- weight

Naturally, not all of these properties are improved at the same time .In fact, some of the properties are in protest with one another.

B. *Fibers:*

Fibers are the principal constituent in a fiber-reinforced composite material. They occupy the largest volume fraction in a composite laminate and share the major portion of the load acting on a composite structure. Proper selection of the type, amount and orientation of fibers is very important, because it influences the following characteristics of a composite laminate

- Specific gravity
- Tensile strength and modulus
- Compressive strength and modulus
- Fatigue strength and fatigue failure mechanisms
- Electric and thermal conductivities
- Cost

In a composite matrix the fibers are surrounded by a thin layer of matrix material that holds the fibers permanently in the desired orientation and distributes an applied load among all the fibers. The matrix also plays a strong role in determining the environmental stability of the composite article as well as mechanical factors such as toughness and shear strength. Because the reinforcing fibers can be oriented during fabrication of item, composites can be tailored to meet increased load demands in specific directions.

- -Glass Fibers
- -Carbon Fiber
- -Aramid Fibers
- -Boron Fibers
- -Silicon Carbide Fiber

C. Glass Fibers:

Glass fibers with polymeric matrices have been widely used in various commercial products such as pipes, tanks, boats and sporting goods. Glass is the most widely used fiber, because of the combination of lower cost, it resist to corrosion, and in many cases efficient manufacturing potential. It has relatively low stiffness, high elongation, and reasonable strength also weight, and generally lower cost relative to other composites. It has been used extensively where it resist to corrosion is important, such as in piping for the chemical industry and in marine applications. It is widely used as a continuous fiber in the textile forms such as cloths and as a chopped fiber in less critical applications. Glass fibers are strong as any of the newly inorganic fibers but they lack rigidity of on account of their structure of molecular. The properties of glasses can be modified to a changing the chemical composition of the glass, but the only glass used to any great restriction in composite materials is ordinary borosilicate glass, known as E-glass.

D. Carbon Fibers:

Carbon fibers, more other fibrous reinforcements, have provided the basis for the development of PMCs as advanced structural engineering materials. Carbon fibers are available with a large variety of tensile moduli ranging from 207 Gpa on the low side to 1035 GPa on the high side. Among the advantages of carbon fibers are their exceptionally high tensile strength, tensile modulus to weight ratios and to weight ratios, very low CTEs (which provide dimensional stability in as space antennas) and high fatigue strengths. Carbon fibers are widely used in aerospace and such as applicable for sporting goods, taking advantages of the relatively high stiffness to weight and high strength to weight ratios of these fibers. The composition and properties of carbon fibers are always dependent on the raw material used the process conditions of manufacture. Carbon fibers are available in three basic forms, namely, long, continue tow, chopped (6-50mm long) and milled (30-3000µm long)

Typical mechanical properties of some commercially procurable carbon fibers are indicated the following table

Fibre	Fibre diameter (µm)	Fibre density (g/cc)	Tensile Strength (GPa)	Tensile Modulus (GPa)
E-Glass	8-14	2.54	3.45	72.4
S-Glass	8-14	2.49	4.58	86.2
Polyethylene	10-12	0.97	2.70	87.0
Aramid (Kevlar 49)	12	1.44	3.62	130.0
HS Carbon, T300	7	1.76	3.53	230
AS4 Carbon	7	1.80	4	228
IM7 Carbon	5	1.80	5.41	276
XUHM Carbon	-	1.88	3.79	428
GY80 Carbon	8.4	1.96	1.96	572
Boron	50-203	2.60	3.44	407
Silicon Carbide	-	3.19	1.52	483

Table 1: Mechanical Properties of Typical Fibers.

II. FORCE CALCULATION

Specifications of a car engine:
Displacement = 2523 cc
Max power = 46.3 KW
Max. Torque = 195 Nm
Transfer gear ratio = 3.78
Torque Calculation: $N_v = V/ (\pi*D)$
$N_v = 905.57$ rpm …………………………………….. (1)
Drive shaft rpm: $N = N_v$*gear Ratio
N = 3423.05 rpm …………. ……………………… (2)
Power: $P = 2*\pi*N*T/60$
T = 129.16 Nm …………………………………… (3)
Abuse torque by considering FOS = 3.5
T applied = 129.16 * 3.5 = 452.07 Nm ………... (4)

III. CAD MODEL GENERATION

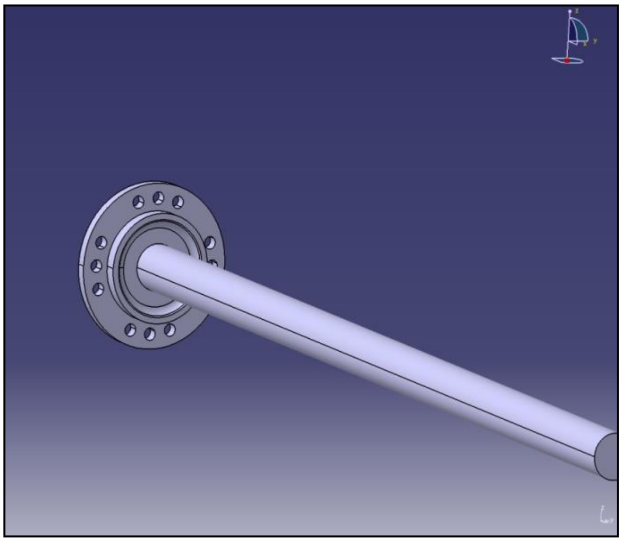

Fig. 2: CAD model of rear axle shaft drawn in CATIAV5

IV. OPTIMIZATION RESULTS

Property	Value
Young's Modulus, E	205 GPa
Poisson's Ratio , ν	0.29
Density, ρ	7850 kg/m^3

Table 2: Material Properties for Steel

A. Von-Mises Stress:

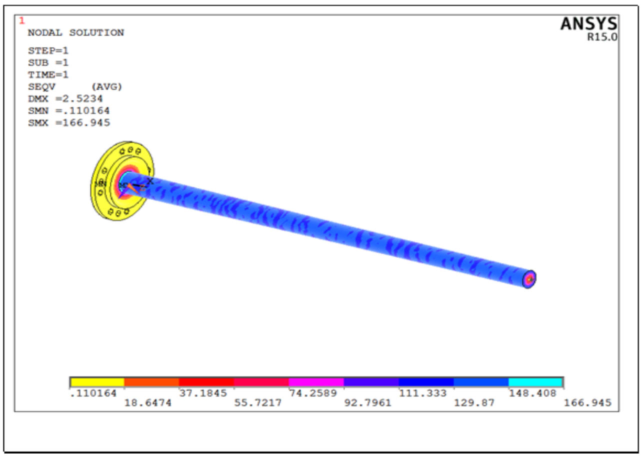

Fig. 3: Von-mises stress for axle shaft

Stress value for trailing arm is 166.94 N/mm2 which is well below the critical value. Hence, design is safe.

B. Displacement:

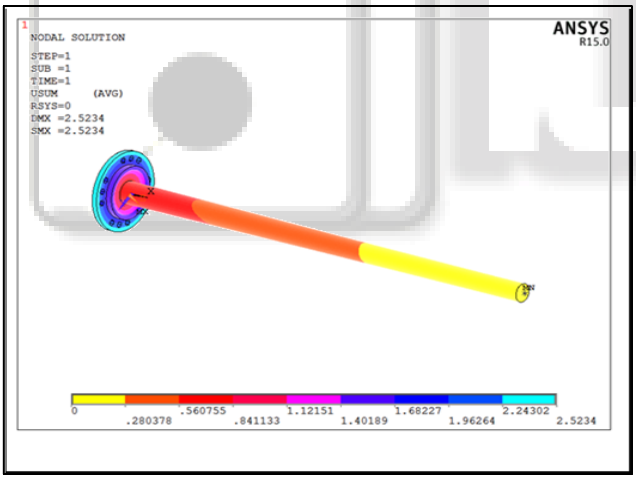

Fig. 4: Displacement for axle shaft

The maximum displacment is coming out to be 2.52 mm which is less.

1) Analysis with Glass Fiber material

Property	Value
E_1	40 Gpa
E_2	6 Gpa
E_3	40 Gpa
Poisson's Ratio (ν)	0.24
G_{xy}	15 Gpa
G_{yz}	2.3 Gpa
Gz_x	15 Gpa
Density, ρ	2000 kg/m^3

Table 3: Material Properties for Glass Fiber

C. Von-Mises Stress:

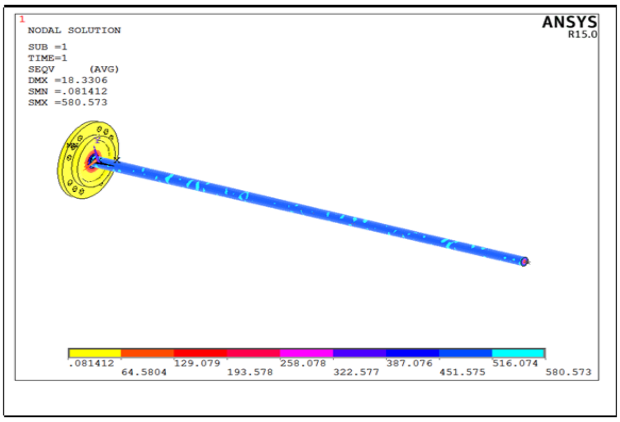

Fig. 5: Von-mises stress for axle shaft

Stress value for trailing arm is 580.57 N/mm^2 which is well below the critical value. Hence, design is safe.

D. Displacement:

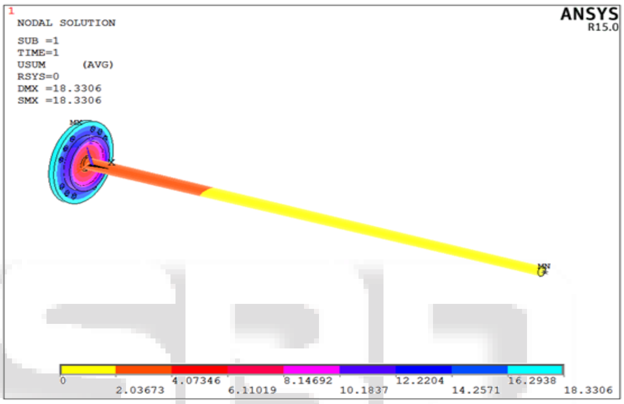

Fig. 6: Displacement for axle shaft

The maximum displacment is coming out to be 18.33 mm

1) Analysis with Carbon fiber material

Mechanical Properties	Units	Carbon Fiber
E_{11}	Gpa	190
E_{22}	Gpa	7.7
G_{12}	Gpa	4.2
ν_{12}	-	0.3
P	Kg / m^3	1600
$S^t_1 = S^c_1$	Mpa	870
$S^t_2 = S^c_2$	MPa	54
S_{12}	MPa	30

Table 4: Material Properties for Carbon Fiber:

E. Von-mises stress:

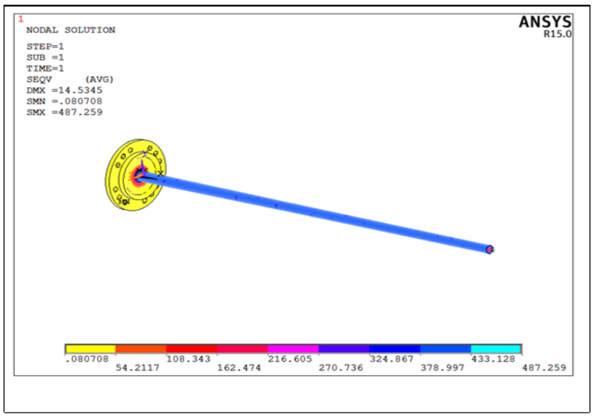

Fig. 7: Von-mises stress for axle shaft

Stress value for trailing arm is 487.25 N/mm2 which is well below the critical value. Hence, design is safe.

F. Displacement:

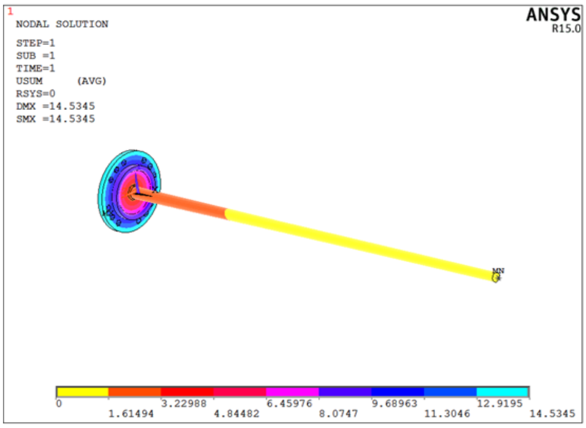

Fig. 8: Displacement for axle shaft

The maximum displacment is coming out to be 14.53 mm

V. Results

A. Comparison:

	Stress, Mpa	Deformation, mm
Existing	166.94	2.52
Glass Fiber	580.57	18.33
Carbon Fiber	487.25	14.53
Hybrid	534.76	16.36

VI. Conclusion

In this paper we have done the analysis on composite drive shaft to increase the efficiency as well as to decrease the cost and weight. By using three different kind of composite materials steel, carbon fiber, glass epoxy/ fiber the project has been carried out. The presented work also deals with design Optimization i.e converting two piece drive shaft (conventional steel shaft) in to single piece light weighted composite drive shaft.

References

[1] Bhirud Pankaj Prakash, Bimlesh Kumar Sinha, “Analysis Of Drive Shaft”, International Journal of Mechanical and Production Engineering, ISSN: 2320-2092

[2] Pandurang V Chopde, Prof. R.B.Barjibhe, “Analysis of Carbon/Epoxy Composite Drive Shaft for Automotive Application”, International Journal of Latest Trends in Engineering and Technology, ISSN: 2278-621X, Vol. 5 Issue 1 January 2015

[3] Bhimagoud Patil, Fayaz Kandagal, Vinoth M.A, “Weight Optimization and FEA Analysis of Al-Si Metal Matrix Composite Drive Shaft” International Journal Of Engineering And Computer Science ISSN:2319-7242, Volume - 3 Issue - 8 August, 2014 Page No. 7713-7717.

[4] Sagar D. Patil, 2Prof. D.S.Chavan, 3Prof. M.V.Kavade, “Investigation of Composite Torsion Shaft for Torsional Buckling Analysis using Finite Element Analysis”, Journal of Mechanical and Civil Engineering, ISSN: 2278-1684 Volume 4, Issue 3 (Nov-Dec. 2012), PP 26-31

[5] M.Arun, K.Somasundara Vinoth, “Design and Development of Laminated Aluminum Glass Fiber Drive Shaft for Light Duty Vehicles”, International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, Volume-2, Issue-6, May 2013

[6] Chaitanya G Rothe, A.S.Bombatkar, “Design and Analysis of Composite Material Drive Shaft”, International Journal of Innovative and Emerging Research in Engineering Volume 2, ISSN- 2394-3343

[7] R. A. Gujar1, S. V. Bhaskar, “Shaft Design under Fatigue Loading By Using Modified Goodman Method”, International Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 3, Issue 4, Jul-Aug 2013, pp.1061-1066

[8] Srimanthula Srikanth, Jithendra Bodapalli, Avinash Gudimetla, “Design, Static and Modal Analysis of A Propeller Shaft for Reducing Vibrations Using Composite Damping”, International Journal of Emerging Technology and Advanced Engineering ISSN 2250-2459.

[9] S V Gopals Krishna, B V Subrahmanyam, and R Srinivasulu,” Finite Element Analysis and optimization of Automotive Composite Drive Shaft”, International Journal of Engineering Trends and Technology (IJETT) – Volume 5 Number 7- Nov 2013

[10] V. S. Bhajantri, S. C. Bajantri, A. M. Shindolkar, S. S. Amarapure, “Design And Analysis Of Composite Drive Shaft”, International Journal of Research in Engineering and Technology, eISSN: 2319-1163 | pISSN: 2321-7308