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"OPTIMIZATION AND ANALYSIS OF DRIVE SHAFT OF AN AUTOMOBILE BY USING E-GLASS/EPOXY AND CARBON/EPOXY"

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ABSTRACT
Almost all vehicles (at least those that correspond to design with rear wheel drive and front engine installation) have transmission shafts. The load reduction of the drive shaft will have a particular role within the general weight reduction of the vehicle and could be an extremely fascinating goal if it may be achieved without a rise in cost and reduction in quality and reliability. It's doable to achieve the design of the composite drive shaft with less weight to increase the natural frequency of the shaft, decrease the bending stresses, maximize the torque transmission and torsional buckling capabilities.

Substituting composite material structure for typical metallic structure has several benefits owing to high specific strength and stiffness of a composite material. This work deals with the replacement of the traditional two-piece drive shaft with a single piece of E-glass/Epoxy, high strength carbon/epoxy, high modulus carbon/epoxy composite drive shaft for an automotive application. The design parameter was optimized with the target of minimizing the weight of the composite drive shaft. The design optimization additionally showed significant potential improvement within the performance of the drive shaft.

Keywords: *Bernoulli Euler theory, static Analysis, Modal analysis, Buckling analysis, ANSYS*

I. INTRODUCTION

The automotive industry is exploiting composite material technology for structural elements construction in order to get the reduction of the weight without the decrease in vehicle quality and reliability [6].The advanced composite materials like graphite, Carbon, Kevlar, and Glass with appropriate resins are widely used as a result of their high specific strength (strength/density) and high specific modulus (modulus/density).Actually, there's nearly a direct proportionality between the weight of a vehicle and its fuel consumption, particularly in city driving.The torque that is produced from the engine and transmission should be transferred to the rear wheel to push the vehicle forward and reverse.These shafts transmit power between the source and also the machines absorbing power. The countershafts, line shafts, overhead shafts, and all industrial shafts are transmission shafts.These shafts form an integral component of the machine. As an example, the crankshaft is an internal part of an I.C. engines slider-crank mechanism [8].

II. DRIVE SHAFT ARRENGEMENT IN A CAR MODEL

Conventional two-piece drive shaft arrangement for rear wheel vehicle driving system is shown in figure 1.1 below.

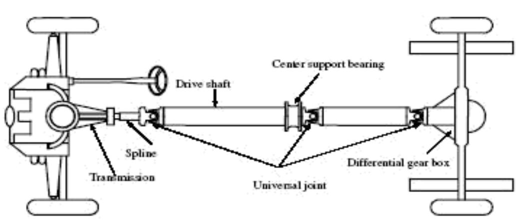

Fig.1.1 Conventional two-piece drive shaft arrangements for rear wheel vehicle driving

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III. PART OF DRIVE SHAFT AND UNIVERSAL JOINT

Parts of drive shaft and universal joint are shown in fig.3.3.Parts of drive shaft and universal joints are:

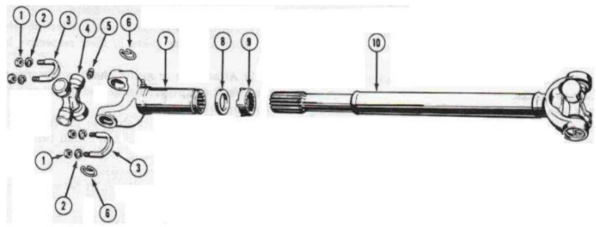


Fig. 1.2 Parts of drive shaft and universal joint.

1. U-bolt nut 2. U-bolt washers
3. U-bolt 4. Universal joint journal
5. Lubrication fitting 6. Snap ring
7. Universal joint sleeve yoke8. Spline seal
9. Dust Cap 10. Drive shaft tube.

IV. COMPOSITE MATERIAL

A material composed of two or more constituents is termed as a composite material. Composite include two or more materials or material phase that combine to provide a material that has superior properties to those of its individual constituents [1].

V. MERITS OF COMPOSITE DRIVE SHAFT

- They have high specific modulus and strength.
- Reduced weight.
- The fundamental natural frequency of the carbon fiber composite driveshaft is often twice as high as that of steel or aluminium as a result of the carbon fiber composite material has more than four times the specific stiffness of steel or aluminium, which makes it doable to manufacture the drive shaft of a passenger car in one price [7]. A one-piece composite shaft is often manufactured so as to satisfy the vibration necessities. This eliminates all the assembly, connecting the two-piece steel shaft and therefore minimizes the overall weight, vibrations and therefore the total cost.
- Due to the weight reduction, fuel consumption is going to be reduced.
- They have high damping capacity thus they produce less vibration and noise.
- They have good corrosion resistance.
- The higher torque capacity than the steel or aluminium shaft.
- Fatigue life is lower than steel or aluminium shaft.
- The more power is transmitted by the lower rotating weights.

VI. CLASSIFICATION OF COMPOSITES

Composite materials are often classified as:

- Chemical compound matrix composites
- Metal matrix composites
- Ceramic matrix

Technologically, the design of fiber-reinforced composites relies on the high strength and stiffness on a weight basis. The ratio between strength and density is a specific strength. The ratio between modulus and density is specific modulus. Fiber length includes a great influence on the mechanical characteristics of a material [11]. The fibers are often either long or short. Long continuous fibers are easy to orient and process, whereas short fibers cannot be controlled completely for proper orientation. Long fibers provide many benefits over short fibers. These include impact resistance, low shrinkage, improved surface end, and dimensional stability. However, short fibers provide low cost, are simple to work with, and have quick cycle time fabrication procedures. The characteristics of the fiber-reinforced composites rely not only on the properties of the fiber but also on the degree to that an applied load is transmitted to the fibers by the matrix part.

The principal fibers in industrial use are varied kinds of glass, carbon, graphite, and Kevlar. All these fibers can be incorporated into a matrix either in continuous lengths or in discontinuous lengths as shown in Fig 1.3. The matrix material could also be a plastic or rubber chemical compound, metal or ceramic. Laminate is obtained by stacking variety of thin layers of fibers and matrix consolidating them to the specified thickness. Fiber orientation in every layer is often controlled to get a good variety of physical and mechanical properties for the composite laminate [6].

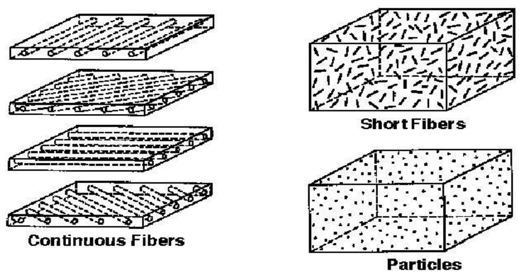


Fig. 1.3 Types of fibers

VII. ADVANTAGES OF FIBER RAINFORSED COMPOSITE

The advantages of composites over the standard materials are:

- •High strength to weight ratio.
- •High damping capacity.

As a result, composite structures may exhibit a higher dimensional stability over large temperature variations.

VIII. COMPARISION WITH TRADITIONAL METAL SHAFT

1. Lower NVH (Noise, Vibration, and Harmonics) Levels
Because of the epoxy matrix of the composite material, the composite shaft has an inherent vibration dampening characteristic [8].

2. Higher rpm Capability
For a fixed diameter and length, a custom, designed carbon shaft can have a higher critical speed than steel, aluminium and titanium shafts. This is due to the low mass density of the carbon fiber/epoxy and therefore the comparatively high axial stiffness of the designed laminate. This results in a shaft that may operate several thousand RPMs more than a metal shaft of constant diameter and length.

3. Lighter Weight
A custom, designed carbon/epoxy shaft is the lightest weight shaft available. In some cases, depending on the dimensions of the metal shaft being replaced, carbon shaft can eliminate many pounds of rotating weight.

4. Torsional Damper
For the same fixed diameter and length, it is possible to engineer a carbon shaft to have a relatively low modulus of rigidity resulting in a shaft with a high torsional flexibility compared to the same size metal shaft. This unique

characteristic will "smooth out" and absorb torque spikes of the engine extending the transmission life.

5. Greater Life Cycle
Since a carbon shaft does not have any welds, there is no metal fatigue. The life cycle of a properly designed carbon shaft will far exceed all types of metal shafts since carbon fibre composite has extraordinarily high fatigue strength. The typical fatigue failure location of metal shafts is in the weld area (heat affected zone).

6. Greater Torsional Strength
All engineered carbon shaft designs are lab tested to failure. One such test is the Ultimate Torsional Test which is conducted to verify the analysis. An engineered carbon shaft will exceed the torsional strength of all metal shafts of the same diameter. Typical failure location of all metal shafts is again in the weld area (heat affected zone). The welding process itself severely weakens the metal material properties of the adjacent metal tube. Any heat treatment of the metal is quickly undone due to the welding temperatures in the heat affected zone.

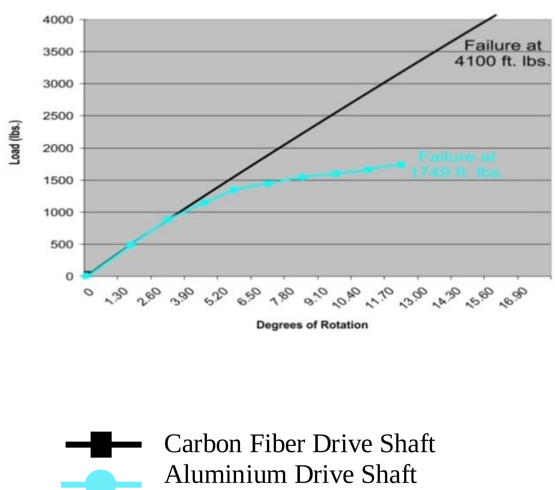
IX. THE ULTIMATE HIGH PERFORMANCE DRIVE SHAFT

The Highest Level of Precision:
The Carbon Fiber Drive Shaft has a near zero T.I.R. T.I.R. (Total Indicator Run out) is any imperfection in form that causes a rotating part, such as a drive shaft to "run-out", that is to not rotate with perfect smoothness [6]. These conditions include being out-of-round, eccentricity or being bent axially. Actually, in fact, there is no need to balance our shafts at all! All of our carbon fiber shafts are inherently balanced due to the precision of its manufacture (not the use of external weights). All other carbon fiber shafts need and use external weights for balancing. Some of the competitor's shafts have a T.I.R. as high as .060".

Unparalleled Durability:
The Carbon Fiber Drive Shaft is the ONLY carbon fiber shaft with a built-in protective outer shell.

Unparalleled Reliability:
This robust design has resulted in a carbon fiber shaft with an impeccable service record. Since its introduction in 2010, the Carbon Fiber Shaft has a 100% reliability rating (no reported failures after years of circle track racing). No other material shaft manufacturer can make this claim.

Highest Level of Safety:



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Since the Carbon Fiber Drive Shaft is the lightest drive shaft…period…it is obviously the safest (less inertia forces if detached from the car due to a track collision). This makes the Carbon Fiber Drive Shaft the safest possible drive shaft for spectators and drivers alike.

Ultra High Strength:
The Carbon Fiber Drive Shaft has an ultimate torsional strength up to 4,100 ft.lbs. (Ref. test results below) which is over 2x stronger than a typical aluminium drive shaft. It is also over 2 ½ x stronger than the 1310 u-joint itself. The 1310 Spicer u-joint has a torsional rating of 1,600 ft.lbs.(minimum elastic limit). This represents the maximum torque load the universal joint will transmit instantaneously without brinelling the bearing or yielding in any part. This may be assumed to be the maximum safe shock load. Therefore, the Carbon Fiber Drive Shaft has an extremely high factor of safety which has contributed to its impeccable service record over the past five years.

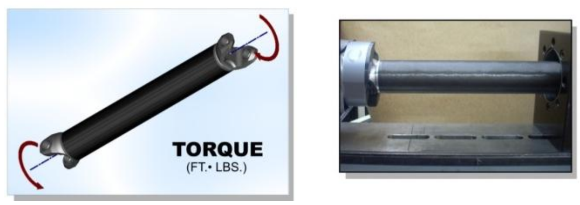

Fig. 1.4 Ultimate Load/Deflection Test

Ultra-Light Weight:

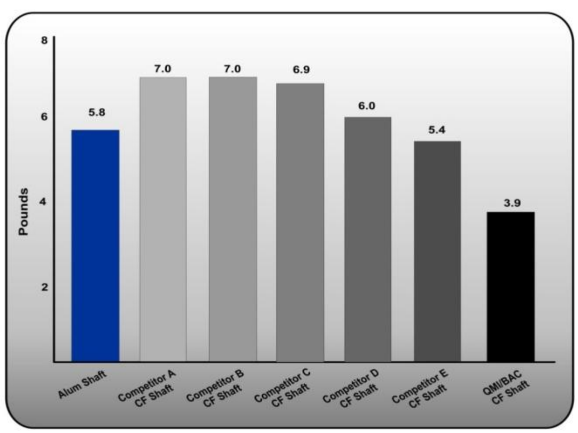

Fig. 1.5 Weight Comparisons

The Carbon Fiber Shaft is up to 3 lbs. lighter than most of the carbon competitors. All of the carbon competitor's shafts weigh as much or even more than a typical aluminium shaft. The carbon fiber shaft is the only shaft that has any performance advantage over an aluminium shaft.

X. LIMITATION OF COMPOSITES

The limitations of composites are, Mechanical characterization of a composite structure is more complex than that of a metallic structure The design of fiber reinforced structure is difficult compared to a metallic structure, mainly due to the difference in properties in directions The fabrication cost of composites is high Rework and repairing are

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difficult They do not have a high combination of strength and fracture toughness as compared to metals in all properties used for material selection [4].

XI. APPLICATION OF COMPOSTITES

The common application of composites is extending day by day. These days they're employed in medical applications too. The opposite fields of applications are,

Automobile: Driveshaft's, clutch plates, engine blocks, pushrods, frames, Valve guides, automotive sports brakes, filament–wound fuel tanks, Fiber Glass/Epoxy leaf springs for serious trucks and trailers, rocker arm covers, suspension arms and bearings for steering mechanism, bumpers, body panels, and doors.

Aircraft: Driveshaft's, rudders, elevators, bearings, landing gear doors, panels and floorings of airplanes etc.

Space: Payload bay doors, remote manipulator arm, high gain antenna, antenna ribs, and struts etc.
Marine: propeller vanes, fans & blowers, gear cases, valves & strainers, condenser shells.

Chemical Industries: Composite vessels for liquid gas for different fuel vehicle, racked bottles for hearth service, mountain climbing, underground storage tanks, ducts, and stacks etc.
Electrical and Electronics: Structures for overhead transmission lines for railways, Powerline insulators, Lighting poles, Fiber optics tensile members etc.

Sports Goods: Court game rackets, Golf club shafts, Fishing rods, Bicycle framework, Hockey sticks, Surfboards, Helmets, and others.

XII. LITERATURE REVIEW

Drive shaft is the most important components of any automobile and equipment's covering a wide range of power transmission applications. Increasing awareness for the effective utilization of energy and materials, optimize the performance and maintenance free operation have led to the development of composite material drive shaft over conventional one.

Experimental Studies:
Deborah D.L. Chung (2015) gives carbon fiber composites in depth review. Carbon fibers refer to fibers which are at least 92 wt. % carbons in composition. They can be short or continuous; their structure can be crystalline, amorphous, or partly crystalline. The crystalline form has the crystal structure of graphite which consists of *Sp2* hybridized carbon atoms arranged two-dimensionally in a honeycomb structure in the *x-y* plane. Carbon atoms within a layer are bonded by covalent bonds provided by the overlap of the *Sp2* hybridized orbitals, and metallic bonding provided by the delocalization of the *pz*orbitals, i.e., the 1T electrons. This delocalization makes graphite a good electrical conductor and a good thermal conductor in the *x-y* plane. The bonding between the layers is van der Waals bonding, so the carbon layers can easily slide with respect to one another; graphite is an electrical insulator and a thermal insulator perpendicular to the layers. Due to the difference between the in-plane and out-of-plane bonding, graphite has a high modulus of elasticity parallel to the plane and a low modulus perpendicular to the plane. Thus, graphite is highly anisotropic. The high modulus of a carbon fiber stems from the fact that the carbon layers, though not necessarily flat, tend to be parallel to the fiber axis. This crystallographic preferred orientation is known as a fiber texture. As a result, a carbon fiber has a higher modulus parallel to the fiber axis than perpendicular to the fiber axis. Similarly, the electrical and thermal conductivities are higher along the fiber axis, and the coefficient of thermal expansion is lower along the fiber axis. The greater the degree of alignment of the carbon layers parallel to the fiber axis, i.e., the stronger the fiber texture, the greater the c-axis crystallite size *(Lc)* , the density, the carbon content, and the fibber's tensile modulus, electrical conductivity, and thermal conductivity parallel to the fiber axis; the smaller the fibber's coefficient of thermal expansion and internal shear strength.

G.J. Withers et al. (2015) modified surface Nano clay reinforced epoxy glass-fiber composite is evaluated for properties of mechanical strength, stiffness, ductility and fatigue life, and compared with the pristine or epoxy glass-fiber composite material not reinforced with Nano clays. The results from monotonic tensile tests of the Nano clay reinforced composite material at 60 °C in air showed an average 11.7% improvement in the ultimate tensile strength, 10.6% improvement in tensile modulus, and 10.5% improvement in tensile ductility vs. these mechanical properties obtained for the pristine material. From tension–tension fatigue tests at a stress-ratio = +0.9 and at 60 °C in air, the Nano clay reinforced composite had a 7.9% greater fatigue strength and a fatigue life over a decade longer or 1000% greater than the pristine composite when extrapolated to 10^9 cycles or a simulated 10-year cyclic life. Electron microscopy and Raman spectroscopy of the fracture and failure modes of the test specimens were used to support the results and conclusions. This Nano composite could be used as a new and improved material for repair or rehabilitation of external surface wall corrosion or physical damage on piping and vessels found in petrochemical process plants and facilities to extend their operational life.

Abdul Samad Khan et al. (2015) developed new techniques that have changed the conventional treatment methods as applications of new dental materials give better outcomes. The current century has suddenly forced on dentistry, a new paradigm regarding expected standards for state-of-the-art patient care. Within the field of restorative dentistry, the incredible advances in dental materials research have led to the current availability of esthetic adhesive restorations. The chemistry and structure of the resins and the nature of the glass fiber reinforced systems in dental composites are reviewed in relation to their influence and properties including mechanical, physical, thermal, biocompatibility, technique sensitivity, mode and rate of failure of restorations on clinical application. It is clear that a deeper understanding of the structure of the polymeric matrix and resin-based dental composite is required. As a result of ongoing research in the area of glass fiber reinforced composites and with the development and advancement of these composites, the future prospects of resin-based composite are encouraging.

Leon Mishnaevsky and Gaoming Dai (2014) study the effect of microstructure of hybrid carbon/glass fiber composites on their strength is presented. Unit cells with hundreds of randomly located and misaligned fibers of various properties and arrangements are subject to tensile and compression loading and the evolution of fiber damages is analyzed in numerical experiments. The effects of fiber clustering, matrix properties, Nano reinforcement, and load sharing rules on the strength and damage resistance of composites are studied. It was observed that hybrid composites under uniform displacement loading might have lower strength than pure composites, while the strength of hybrid composites under inform force loading increases steadily with increasing the volume content of carbon fibers.

XIII. RESULT AND DISCUSSION

Comparative results of Analytical study and Modeling study for Drive Shaft
Analytical Study

Table: Result of Analytical Study

Material	**Steel**	**E-Glass/ Epoxy**	**HS Carbon/ Epoxy**
T (Nm)	3733.44	3893.86	4005.70
Fnb (Hz)	160.89	112.98	127.71
t (mm)	3.318	6.80	2.04
Mass (Kg)	8.604	4.443	1.1273
% Saving	-	48.36%	85.2%

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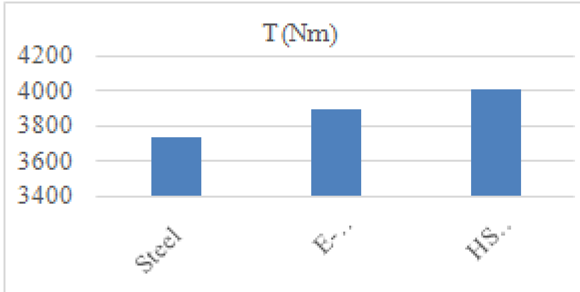

Fig.Torsional Buckling Capacity of Drive Shaft

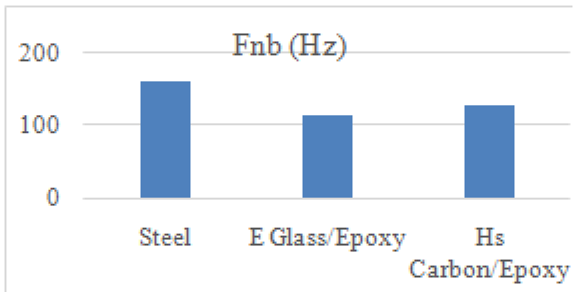

Fig.Bending Natural Frequency of Drive Shaft

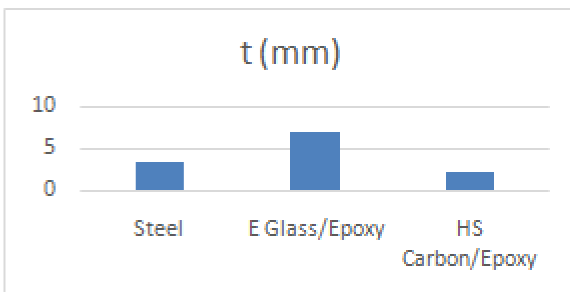

Fig.Thickness of Drive Shaft

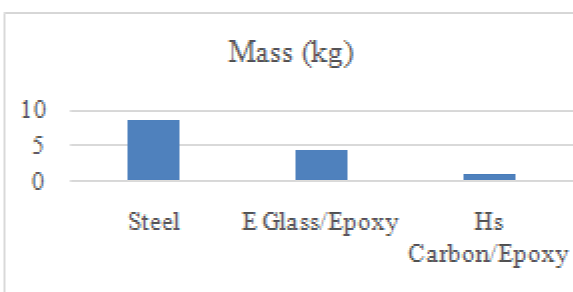

Fig. Mass of the Drive Shaft

Table: Comparative result of Analytical and Modeling study of drive shaft

SN	Material	Analytical Study			Modeling Study		
		T(Nm)	F(Hz)	M(kg)	T(Nm)	F_n(hz)	M(kg)
1	Steel	3733.4	160.89	8.604	3815.9	158.3	8.504
2	E-Glass/Epoxy	3893.9	112.98	4.443	4087.8	111	4.511
3	HS-Carbon /Epoxy	4005.7	127.71	1.1273	4189.1	125.1	1.1283

XIV. CONCLUSION

The following conclusions are drawn from the present work.
1) The E-Glass/ Epoxy, and High Strength Carbon/Epoxy shafts have been designed to replace the steel drive shaft and conventional composite drive shaft of an automobile [6].
2) A one-piece composite drive shaft for rear wheel drive automobile has been designed for E-Glass/ Epoxy and High Strength Carbon/Epoxy composites with the objective of minimization of weight and increase life of the shaft which was subjected to the constraints such as torsional buckling capacities and natural bending frequency [8].
3) The weight savings of the E-Glass/ Epoxy and High Strength Carbon/Epoxy shafts were equal to 48.36%, 86.90% and 86.90% of the weight of steel shaft respectively.
4) By using CLT, the variations of the stresses and strains along thickness of the E-Glass/ Epoxy and High Strength Carbon/Epoxy composite drive shafts were plotted CLT. It has been observed that all the stresses were within the allowable limit.
5) The deflection of Steel, E-Glass/ Epoxy and High Strength Carbon/Epoxy shafts were equal to 0.012407, 0.025262, and 0.019288 mm respectively.
6)The torsional buckling capacity of E-Glass/ Epoxy, High Strength Carbon/Epoxy and High Modulus Carbon/Epoxy shafts were 3893.86, 4005.70, 4365.54 (N-m) respectively.
7) The torque transmission capacity of the composite drive shafts has been calculated by neglecting and considering the effect of centrifugal forces and it has been observed that centrifugal forces will reduce the torque transmission capacity of the shaft
8)Bending natural frequency of HS Carbon/Epoxy drive shaft is nearly equal to steel drive shaft so less chances of failure. So the life of HS Carbon/Epoxy and HM carbon/epoxy drive shaft is more, compare to other composite material drive shaft [8].

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