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Review Article

Experimental Analysis of Automobile propeller shaft by using hybrid composite materials: A Review

A.A.Jadhav* **and L. B. Raut**

Department of Mechanical Engineering, SVERI'S College of Engineering, Pandharpur, Taluka-Pandharpur, District-Solapur, Pin-413304, Maharastra, India

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Abstract

This paper presents the review of the studies carried out on the replacement of conventional steel driveshaft of automobiles with an appropriate composite driveshaft with different combinations of fibres at a time. For reducing the bending natural frequency the conventional steel shafts are made in two pieces, where to reduce the overall weight the composite material drive shaft is made in single piece.Various composites were designed and analyzed for their appropriateness in terms of torsional strength, bending natural frequency and torsional buckling by comparing them with the conventional steel driveshaft under the same grounds of design constraints and the best-suited composite was recommended. Light has been thrown upon the aspects like mass saving, number of plies and ply distribution.

Keywords: *Hybrid, natural frequency, buckling, ply distribution.*

1. Introduction

A driveshaft is a rotating shaft that transmits power from the engine to the differential gear of a rear wheel drive vehicles Driveshaft must operate through constantly changing angles between the transmission and axle.To increase the natural frequency the drive shaft is manufactured in two pieces. The steel drive shaft with two pieces has three universal joints and one bearing at the centre. We can improve the power transmission by reducing the weight and mass inertia.So we replace conventional steel with composite materials. The composite materials have high strength and high stiffness. We can use different combinations of composite materials.for purpose of higher strength we use two or three materials at once to get higher strength.

Categories of composite material

Composites are classified by the geometry of the reinforcement - Particulate, Flake, and Fibres.

Particulate composites: It consists of particles immersed in matrices such as alloys and ceramics. They are usually isotropic because the particles are added randomly. Particulate composites have advantages such as improved strength, increased operating temperature, oxidation resistance, etc. Typical examples include use of aluminium particles in rubber, silicon carbide particles in aluminium, and gravel, sand, and cement to make concrete.

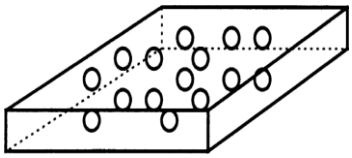

Fig. 1 Particulate composite

Flake Composites: It consists of flat reinforcements of matrices. Typical flake materials are glass, mica, aluminium, and silver. Flake composites provide advantages such as high out-of-plane flexural modulus, higher strength, and low cost. However, flakes cannot be oriented easily and only a limited number of materials are available for use.

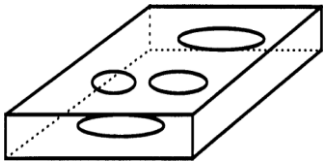

Fig. 2. Flake composite

Fibre composites: It consist of matrices reinforced by short (discontinuous) or long (continuous) fibres.

Correponding author's ORCID ID: 0000-0003-1439-8788

Fibres are generally anisotropic and examples include carbon and aramids. The Examples of matrices are resins such as epoxy, metals such as aluminium, and ceramics such as calcium–alumino silicate. The fundamental units of continuous fibre matrix composite are unidirectional or woven fibre laminas. Laminas are stacked on top of each other at various angles to form a multidirectional laminate.

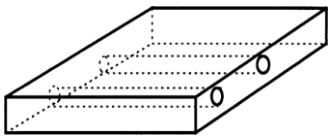

Fig.3. Fibre composite

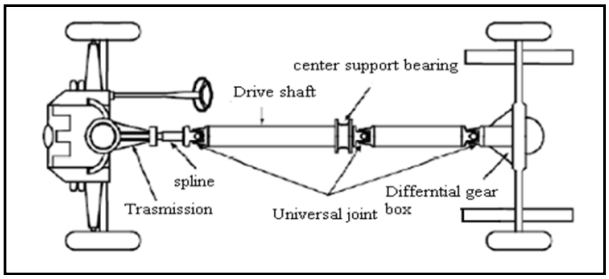

Fig.4 Conventional two-piece steel drive shaft for a rear wheel drive vehicle

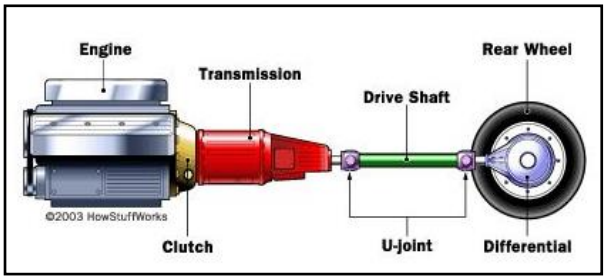

Fig.5 Advanced one piece composite drive shaft for rear wheel drive vehicle

Advanced polymer composites

These polymers include epoxy, phenolic, acrylic, urethane, and polyamide. Each polymer has its advantages and drawbacks in its use:

1. Polyesters: The advantages are low cost and the ability to be made translucent; drawbacks include service temperatures below 170°F (77°C), brittleness, and high shrinkage of as much as 8% during curing.

2. Phenolic: The advantages are low cost and high mechanical strength; drawbacks include high void content.

3. Epoxies: The advantages are high mechanical strength and good adherence to metals and glasses; drawbacks are high cost and difficulty in processing.

4. Epoxy: Epoxy resins are the most commonly used resins. They are low molecular weight organic liquids containing epoxide groups. Epoxide has three members in its ring: one oxygen and two carbon atoms. The reaction of epichlorohydrin with phenols or aromatic amines makes most epoxies. Hardeners, plasticizers, and fillers are also added to produce epoxies with a wide range of properties of viscosity, impact, degradation, etc.

Table 1 Properties of Epoxy

Sr. No.	Properties	Epoxy	Units
1.	Specific gravity	1.28	-
2.	Young's modulus	3.80	GPa
3.	Ultimate tensile strength	82.79	MPa

Although epoxy is costlier than other polymer matrices, it is the most popular PMC matrix. More than two-thirds of the polymer matrices used in aerospace applications is epoxy based. The main reasons why epoxy is the most used polymer matrix material are

- High strength.
- Low viscosity and low flow rates, which allow good wetting of fibers and prevent misalignment of fibers during processing.
- Low volatility during cure.
- Low shrink rates, which reduce the tendency of gaining large shear stresses of the bond between epoxy and its reinforcement
- Available in more than 20 grades to meet specific property and processing requirements.

2. Literature Review

Following is the literature review of some papers giving more information about their contribution in composite field for replacement of metallic drive shaft.Some of the researchers doing their work in hybrid composite material in automobile area.

Dai Gil Lee, *et.al* Investigated one-piece automotive hybrid aluminium composite drive shaft with a new manufacturing method, in which a carbon fibre epoxy composite layer was co-cured on the inner surface of an aluminium tube rather than wrapping on the outer surface to prevent the composite layer from being damaged by external impact and absorption of moisture. The optimal stacking sequence of the composite layer was determined considering the thermal residual stresses of interface between the aluminum tube and the composite layer calculated by finite element analysis. From experimental results, it was found that the developed one-piece automotive hybrid aluminum composite drive shaft had 75% mass reduction, 160% increase in torque capability compared with a conventional two-piece steel drive shaft. It also discussed 9390 rpm of natural frequency which was higher than the design specification of 9200 rpm. This paper gives additional support for how to select stacking sequence and its effect on performance on composite materials.

Harshal Bankar, *et.al* In metallic drive shaft by a composite drive shaft. The following materials can be

chosen Steel, Boron/Epoxy Composite, Kevlar/Epoxy Composite, Aluminum–Glass/Epoxy Hybrid, and 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 and light commercial vehicle.

Dai Gil Lee, *et.al* A carbon fiber epoxy composite layer was co-cured on the inner surface of an aluminum tube rather than wrapping on the outer surface to prevent the composite layer from being damaged by external impact and absorption of moisture. The optimal stacking sequence of the composite layer was determined considering the thermal residual stresses of interface between the aluminum tube and the composite layer calculated by finite element analysis. Press fitting method for the joining of the aluminum/composite tube and steel yokes was devised to improve reliability and to reduce manufacturing cost, compared to other joining methods such as adhesively bonded, bolted or riveted and welded joints. Protrusion shapes on the inner surface of steel yoke were created to increase the torque capability of the press fitted joint. From experimental results, it was found that the developed one-piece automotive hybrid aluminum/composite drive shaft had 75% mass reduction, 160% increase in torque capability compared with a conventional two-piece steel drive shaft. It also had 9390 rpm of natural frequency which was higher than the design specification of 9200 rpm.

R.Srinivasa Moorthy, *et.al* Aim of this work is to replace the conventional steel driveshaft of automobiles with an appropriate composite driveshaft. 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. Carbon/Epoxy and Kevlar/Epoxy composites were designed and analyzed for their appropriateness in terms of torsional strength, bending natural frequency and torsional buckling by comparing them with the conventional steel driveshaft under the same grounds of design constraints and the best-suited composite was recommended. Light has been thrown upon the aspects like mass saving, number of plies and ply distribution.

Sunil Mangsetty, *et.al* Composite materials have been used in automotive components because of their properties such as low weight, high specific stiffness, corrosion free, ability to produce complex shapes, high specific strength and high impact energy absorption etc .As the automotive drive shaft is a very important component of vehicle. The modeling of the drive shaft assembly was done using CATIA software. In present work an attempt has been to estimate deflection, stresses under subjected loads & natural frequencies using FEA.

Hargude N.V., *et.al* The Main aim of this work is to investigate either replacing steel structure of drive shaft for rear wheel drive passenger cars by composite structures such as carbon/Epoxy and Glass/Epoxy materials will be convenient or not. For finding out the suitability of composite structures for automotive drive shaft application the parameters such as, ply thickness, number of plies and stacking sequence are optimized for carbon/Epoxy and Glass/Epoxy shafts using Genetic Algorithm as an optimization tool with the objective of weight minimization of the composite shaft which is subjected to constraints such as torque transmission, torsional buckling load and fundamental natural frequency.Carried out an investigation of maximum torque, buckling torque transmission and critical speed of composite drive shaft. The Main aim of this work was to investigate either replacing steel structure of drive shaft for rear wheel drive passenger cars by composite structures such as carbon/Epoxy and Glass/Epoxy materials will be convenient or not. For finding out the suitability of composite structures for automotive drive shaft application the parameters such as ply thickness, number of plies and stacking sequence are optimized for carbon/Epoxy and Glass/Epoxy shafts using Genetic Algorithm as an optimization tool with the objective of weight minimization of the composite shaft which is subjected to constraints such as torque transmission, torsional buckling load and fundamental natural frequency In addition to the issue addressed in this paper optimization technique is used for thickness of ply, number of ply and stacking Sequence. This gives us direct reference for selection of above parameters to our dissertation work.

Parshuram D, *et.al* reduced the weight of automotive drive shaft with the utilization of composite material. The modeling of the drive shaft assembly was done using CATIA software. A shaft has to be designed to meet the stringent design requirements for automotives. In automobiles the drive shaft is used 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 rear wheel-driving vehicle. In present work an attempt has been to estimate deflection, stresses under subjected loads & natural frequencies using FEA. From this paper FEA analysis study is referred for our project to find out natural frequency.

M.A. Badie,*et.al* This paper examines the effect of fiber orientation angles and stacking sequence on the torsional stiffness, natural frequency, buckling strength, fatigue life and failure modes of composite tubes. Finite element analysis (FEA) has been used to predict the fatigue life of composite drive shaft (CDS) using linear dynamic analysis for different stacking sequence. Experimental program on scaled woven fabric composite models was carried out to investigate the torsional stiffness. FEA results showed that the natural frequency increases with decreasing fiber

orientation angles. The CDS has a reduction equal to 54.3% of its frequency when the orientation angle of carbon fibers at one layer, among other three glass ones, transformed from 0_ to 90_. On the other hand, the critical buckling torque has a peak value at 90_ and lowest at a range of 20–40_ when the angle of one or two layers in a hybrid or all layers in non-hybrid changed similarly. Experimentally, composite tubes of fiber orientation angles of ±45_ experience higher load carrying capacity and higher torsional stiffness. Specimens of carbon/epoxy or glass/epoxy composites with fiber orientation angles of ±45_ show catastrophic failure mode. In a hybrid of both materials, [±45_] configuration influenced the failure mode.

Arun Ravi, *et.al* The weight reduction of the drive shaft can have a certain role in the general weight reduction of the vehicle and is a highly desirable goal ,if it can be achieved without increase in cost and decrease in quality and reliability. It is possible to achieve design of composite drive shaft with less weight to increase the first natural frequency of the shaft and to decrease the bending stresses using various stacking sequences. By doing the same, maximize the torque transmission and torsional buckling capabilities are also maximized. This work deals with the replacement of a conventional steel drive shaft with High Strength Carbon drive shafts for an automobile application.

Brahmaiah, *et.al* In this paper an attempt is made to evaluate the suitability of composite material for the purpose of automotive drive shaft application. A Static and Dynamic analysis, composite shaft is analyzed using Finite Element Analysis Software for composites with the objective of minimizing the weight of the shaft, which is subjected to the constraints such as torque transmission, critical buckling torque capacity and also we are modifying the geometric shape to improve efficiency.

Narayana, *et.al* The advanced composite materials such as graphite, carbon, Kevlar and Glass with suitable resins are widely used because of their high specific strength and high specific modulus & fatigue strength. Advanced composite materials use ideally suited for long power driver shaft applications. The present work includes, analysis done on drive shaft of Toyota qualis with different composite materials and concludes that the use of composite materials for drive shaft would induce less amount of stress which additionally reduces the weight of the vehicle. CATIA V5R16 is the modeling package used to model the drive shaft assembly and ANSYS 11.0 is the analysis package used to carry out analysis.

Mutasher This paper investigates the maximum torsion capacity of the hybrid aluminum/composite shaft for different winding angle, number of layers and stacking sequences. The hybrid shaft consists of aluminum tube wound outside by E-glass and carbon fibers/epoxy composite. The finite element method has been used to analyze the hybrid shaft under static torsion. ANSYS finite element software was used to perform the numerical analysis for the hybrid shaft. Full scale hybrid specimen was analyzed. Elasto-plastic properties were used for aluminum tube and linear elastic for composite materials. The results show that the static torque capacity is significantly affected by changing the winding angle, stacking sequences and number of layers. The maximum static torsion capacity of aluminum tube wound outside by six layers of carbon fiber/epoxy composite at winding angle of 295 N m. Good agreements was obtained between the finite element predictions and experimental results.

Mahmood M. Shokrieh *et.al* In this research the torsional stability of a composite drive shaft torsion is studied. Composite materials are considered as the suitable choice for manufacturing long drive shafts. The applications of this kind of drive shafts are developed in various products such as cars, helicopters, cooling towers, etc. From the design point of view, local and global torsional instability of drive shafts limits the capability for them to transfer torque. After reviewing the closed form solution methods to calculate the buckling torque of composite drive shafts, a finite element analysis is performed to study their behavior. Furthermore, to evaluate the results obtained by the finite element method, a comparison with experimental and analytical results is presented. A case study of the effects of boundary conditions, fiber orientation and stacking sequence on the mechanical behavior of composite drive shafts is also performed. Finally, the reduction of the torsional natural frequency of a composite drive shaft due to an increase of applied torque is studied.

Ercan Sevkat *et.al* In this study, the torsional behavior of hybrid composite shafts was examined by a combined experimental and numerical approach. Glass and carbon fiber reinforced hybrid shafts with three lay-up sequences were manufactured using filament winding technique. All three shafts had same amount of glass and carbon fiber. Angular velocities of 0.1_/min and 5_/min were used as torsion test speeds. The effect of torsional strain-rate and lay-up sequences on the response of hybrid shafts was studied. Torque–twisting angle changes were recorded. Test results revealed that changing angular velocities did not affect the torsional behavior of composite shafts significantly. However, three different lay-up sequences resulted in remarkably different torsional behavior. Torsional behavior of composite shafts was simulated using Finite Element software, Abaqus. The elastic orthotropic composite model was used for simulations. FE models were validated using experimental test results. Numerically and experimentally obtained results exhibited quite similar torsional behavior.

S. Misri *et.al* This paper investigates the synthetic fiber is of higher strength in composites and is a low cost material, but the problem is that it does not degrade in the environment. Studies on single yarn natural fiber have been reported, especially those concerned with improving its mechanical properties. This can be used for lower end applications such as

furniture and automotive dash board to reduce the utilization of synthetic fiber. Continuous yarn fibers are required to increase the strength for engineering applications and filament winding is a method to produce aligned technical composites which have high fiber content. This paper presents an experimental and simulation studies to investigate the behavior of composite hollow shafts, with a specific focus on the maximum torsion capacity of the composite hollow shaft for different winding angles and aluminum reinforcement. The conventional filament winding machine was modified and added to a new resin bath mechanism in order to produce a new natural fiber composite hollow shaft using kenaf yarn fibre reinforced with unsaturated polyester resin. The results show that the torsion capacity is significantly affected by changing the winding angle and the presence of aluminum in the static torque test capacity properties. The maximum static torsion capacity of kenaf yarn fibre reinforces unsaturated polyester composite shaft at a winding angle of 45^0 was higher strength than 90^0 orientation while the presence of aluminum enhanced the torsion property significantly. Finite element analysis (FEA) using Abacus software was carried out and showed a good agreement with the experimental results.

3. Result and Discussion

From above literature review, it is observed that both finite element analysis and experimental result were presented.many reseachers presented the effect of the stacking sequence, no of layers, angle orientation and volume fraction on the mechanical properties such as Young's modulus, shear modulus,poissions ratio,density etc,in composite hybrid material.

Many of researchers presented effect of stacking sequence, no of layers, angle orientation and volume fraction on the natural bending frequency,shear strength,critical speed etc.

Conclusion

The paper presented a literature review realted with the studies on effect of various changes in comopisite hybrid material such as number of layers,thickness of layer, layerwise sequence and angle orientation angle orientation.

From the above literature review, it is observed that various tools such as ANSYS,FFT Analyzer test,torsional test,tensile and shear test of laminates can be tested effectively and validated by FEA as well as analyatical and finally suggested the how better replacement of metallic drive shaft by hybrid composite matrial drive shaft.

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