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Review Article

Design and Analysis of Drive Shaft by using Hybrid Composite Material: A Review

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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 fibers 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 aluminum particles in rubber, silicon carbide particles in aluminum, and gravel, sand, and cement to make concrete.

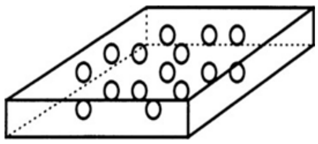

Fig. 1 Particulate composite

Flake Composites: It consists of flat reinforcements of matrices. Typical flake materials are glass, mica, aluminum, 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.

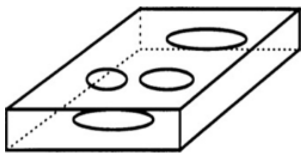

Fig. 2. Flake composite

Fiber composites: It consists of matrices reinforced by short (discontinuous) or long (continuous) fibres. Fibres are generally anisotropic and examples include carbon and aramids. The Examples of matrices are resins such as epoxy, metals such as aluminum, and

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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.

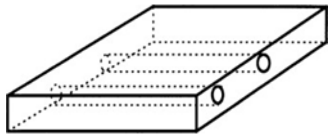

Fig.3. Fibre composite

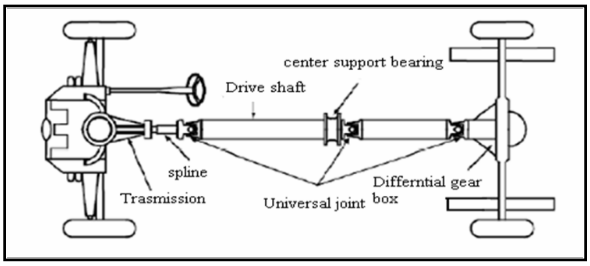

Fig.4 Conventional two-piece steel drive shaft for a rear wheel drive vehicle

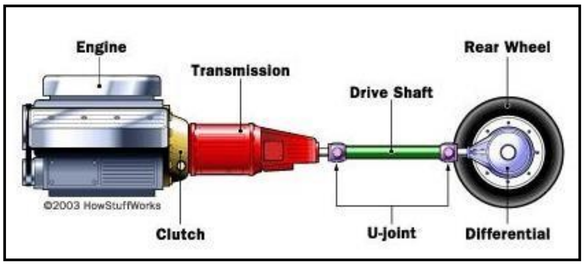

Fig.5 Advanced one piece composite drive shaft for rear wheel drive vehicle

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.

Die Gil Lee, *et.al* Substituting composite structures for predictable metallic structures has many compensation because of advanced specific stiffness and higher specific strength of composite material. In this work, one-piece automotive hybrid aluminum/composite drive shaft was developed with new manufacturing method. The composite material was stacked on the inner surface of the aluminum and co-cured prevent the hybrid shaft from being damaged by external impact and moisture. 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 series for the composite stacked on inner surface of the aluminum tube was firm considering thermal residual stress induced during co-curing operation.

S. A. Mutasher, *et.al* A Hybrid aluminum /composite is an advanced composite material that consist of aluminum tube wound on to outside by layers of composite material. The result from this combination is a hybrid shaft that has a higher torque transmission capability, a higher fundamental natural bending frequency and less noise and vibration. 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 fiber/epoxy composite. The finite element method has been used to analyze the hybrid shaft under static torsion.

A. R. Abu Talib, *et.al* In this study a finite element analysis was used to design composite drive shaft incorporating carbon and glass fiber within an epoxy matrix. A configuration of one layer of carbon-epoxy and three layers of glass –epoxy with 0^0, 45^0, and 90^0 was used. The developed layers of structure consist of four layers stacked as [$+45^0_{glass}$ / -45^0_{glass}/ 0^0_{carbon}/ 90^0_{glass}]. The result show that, in changing carbon fibers winding angle from 0^0 to 90^0 the loss in natural frequency of the shaft is 44.5%, while shifting from best to the worst stacking sequence, the drive shaft causes a loss of 46.07% in its buckling strength, which represents the major concern over shear strength in drive shaft design.

Prajitsen Damle, *et.al* The study of replacement of conventional two-piece steel drive shaft with one-piece automotive hybrid aluminum/composite drive shaft and was developed with a new manufacturing method in which 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 replacing composite structure with conventional metallic structure has many advantages because of higher specific stiffness and higher specific strength of composite material.

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

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 mode of composite tube. Finite element analysis has been used to predict the fatigue life of composite drive shaft 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.

Hak Sung Kim, *et.al* In this work the low velocity impact damage characteristics of aluminum/composite hybrid drive shaft were investigated. The hybrid drive shaft was manufactured by stacking carbon epoxy composite prepregs and insulating layer for galvanic corrosion on the inner surface of the aluminum tube, and co-curing them in an autoclave under recommended cure cycle. After impacting the co-cured hybrid drive shafts using drop weight impact tester, the damage and delaminating of the composite layer Were observed with an ultrasonic C-scan, from which the damage mode of aluminum/composite hybrid shaft were found with respect to stacking sequence of composite materials, the thickness of aluminum tube and the impact energy. Finally, optimal stacking sequence of the composite material and optimal thickness of the aluminum tube for the drive shaft for low velocity impact were suggested.

Hak Sung Kim, *et.al* In this work, a one-piece hybrid drive shaft composed of aluminum and carbon/epoxy composite was designed for rear wheel drive automobile. The aluminum yoke was joined to the hybrid shaft by the press fit joining method using a steel ring which has many small teeth to increase reliability and to reduce manufacturing cost. To obtain high strength of the press fit joint, an optimal design method for the teeth was devised with respect to number and shape of the steel teeth. The developed optimal design method predicted well the static torque capability and failure mode of the press fit joint.

Pardeshi Aditya J, *et.al* Application of superior composites has resulted in great success in many fields such as aviation, marine and automobile engineering, medicine, prosthetics and sports, in terms of better fatigue and corrosion resistances, high specific strength and specific modulus and reduction in energy requirements ultimately resulting reduction in weight. So manufacturing of the automotive components from high strength, high stiffness FRP in order to decrease weight and fuel consumption has been under discussion. Automotive drive Shaft is a very significant component of vehicle. The purpose of this paper is to design and examine a hybrid drive shaft for power transmission. This project deals with the replacement of conventional two-piece steel drive shafts with a hybrid material.

A. A. Jadhav, *et.al* 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 fibers 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.

Harshal Bankar, *et.al* The objective of the drive shaft is to connect with the transmission shaft with the help of universal joint whose axis intersects and the rotation of one shaft about its own axis results in rotation of other shaft about its axis. Automobile industries are exploring composite materials in order to obtain reduction of weight without significant decrease in vehicle quality and reliability. Particularly in city driving, the reduction of weight is almost directly proportional to fuel consumption of the vehicle. Also at the start of vehicle the most of the power get consumed in driving transmission system, if we able to reduce the weight of the propeller shaft that surplus available power can be used to propel the vehicle. Thus, in this paper, the aim is to replace a two-piece 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, Carbon – Glass/Epoxy Hybrid.

Sunilkumar M. Bandgar, *et.al* The drive shaft is a very important component of an automobile. By adding composite materials for conventional metallic structures have many advantages such as higher specific strength and stiffness of the composite materials. The aim of this work is examines the maximum torsion capacity of hybrid drive shaft for number of layers, different winding angles and stacking sequences. The hybrid shaft contains of aluminum tube wound outside by carbon fibers/epoxy composite.

Fanlong Chen, *et.al* This paper details a novel morphing composite propeller (MCP) to improve the performance for marine vehicles (MVs). A MCP is designed with an active rotatable flap (ARF) to change the blade's local camber with flap rotation. A piezo-stack actuator has been connected with one transmission mechanism housed in the propeller blade to push the ARF to obtain various configuration of the MCP. A commercial Finite Element (FE) software ANSYS Fluent was employed to analyze and simulate the hydrodynamics around the propeller with the ARF ranging from _5_ to +5_ and the advance speeds ranging from 1.08 to 2.52 m/s. Finally, the FE results has been used to predict improved performances of the MCP and found the morphing

Composite propeller configuration has improved the efficiency by 1.1% while improving the structural durability.

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. 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.

Ercan Sevkat, *et.al* This paper presents an experimental and numerical study to investigate residual torsional properties of composite shafts subjected to impact loadings. E-glass/epoxy, carbon/epoxy and E-glass–carbon/epoxy hybrid composite shafts were manufactured by filament winding method. Torque-twisting angle relations for each test were obtained. Reduction at maximum torque and maximum twisting angle induced by impact loadings were calculated. The 3-D finite element (FE) software, Abacus, incorporated with an elastic orthotropic model, was then used to simulate the torsion tests. Good agreement between experimental and numerical results was achieved.

2. Result and Discussion

From over literature review, it is experimental that both finite element analysis and experimental result were presented. many researchers 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 related with the studies on effect of various changes in composite hybrid material such as number of layers, thickness of layer, layer wise 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 analytical and finally suggested the how better replacement of metallic drive shaft by hybrid composite martial drive shaft.

References

Die Gil Lee, *et.al*, (2004) Design and manufacture of an automotive hybrid aluminum/composite drive shaft Department of Mechanical Engineering, ME3261, Korea Advanced Institute of Science and Technology, 373-1 Guseong-dong, Yuseong-gu, Daejeon-shi 305-701, South Korea.

S. A. Mutasher, *et.al*, (2009) Prediction of the torsional strength of the hybrid aluminum/composite drive shaft School of Engineering, Swinburne University of Technology (Sarawak Campus), Tingkat 1, Komplekes Negeri, Jalan Simpang Tiga, 935576 Kuching, Sarawak, Malaysia.

A. R. Abu Talib, *et.al*, (2010) Developing a hybrid, carbon/glass fiber-reinforced, epoxy composite automotive drive shaft Department of Mechanical and Manufacturing Engineering, University Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.

Prajitsen Damale, *et.al*, (2013) Review of Design of Hybrid Aluminum/ Composite Drive shaft for Automobile International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-2, Issue-4, March 2013, Pages-259-266

Sunil Mangsetty, *et.al*, (2013) Design and Analysis of Composite/Hybrid Drive Shaft for Automotives, The International Journal of Engineering and Science (IJES), Volume-2, Issue-01, 2013, Pages- 160-171.

M. A. Badie, *et.al*, (2011) An investigation into hybrid carbon/glass fiber reinforced epoxy composite automotive drive shaft Mechanical and Industrial Engineering Department, College of Engineering, Qatar University, P.O. Box 2713, Doha, Qatar

Hak Sung Kim, *et.al*, (2004) Foreign objects impact damage characteristics of aluminum/composite hybrid drive shaft Department of Mechanical Engineering, ME3261, Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon-shi 305-701, Republic of Korea Available online 2 June 2004.

Hak Sung Kim, *et.al*, (2005) Optimal design of the press fit joint for a hybrid aluminum/composite drive shaft Department of Mechanical Engineering, ME3261, Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon-shi 305-701, South Korea Available online 13 September 2004.

Pardeshi Aditya J, *et.al*, (2016) Review on Design And Analysis of Hybrid Drive Shaft International Journal of Emerging Technology and Innovative Engineering Volume 2, Issue 4, April 2016 (ISSN: 2394 – 6598).

A. A. Jadhav, (2017) *et.al*, Experimental Analysis of Automobile propeller shaft by using hybrid composite materials International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Harshal Bankar, *et.al*, (2013) Material Optimization and Weight Reduction of Drive Shaft Using Composite Material IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 10, Issue 1 (Nov. - Dec. 2013), PP 39-46.

Sunilkumar M. Bandgar, *et.al*, (2004) Automotive Composite Hybrid Drive Shaft International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056.

Fanlong Chen, *et.al*, (2017) The study on the morphing composite propeller for marine vehicle. Department of Astronautical Science and Mechanics, Harbin Institute of Technology, Harbin 150001, People's Republic of China.

Ercan Sevkat, *et.al*, (2014) Effect of torsional strain-rate and lay-up sequences on the performance of hybrid composite shafts Department of Mechanical Engineering, Meliksah University, 38280 Talas, Kayseri, Turkey.

Ercan Sevkat, *et.al*, (2015) Residual torsional properties of composite shafts subjected to impact loadings Department of Mechanical Engineering, Meliksah University, 38280 Talas, Kayseri, Turkey