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A Critical Review: Application of Epoxy-Non Metal Composite Material for Automobile Propeller Shaft.

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Abstract: Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. In the recent days, there is a huge demand for a light weight material such as fiber reinforced polymer composites seems to be a promising solution to this arising demand. These materials have gained attention due to their applications in the field of automotive, aerospace, sports goods, medicines and household appliances. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This study represents the work done by various researchers and their methodologies.

Keywords: Conventional shaft, drive shaft, composite shaft, composite material.

I. INTRODUCTION

A driveshaft is a rotating shaft that transmits drive to wheels. Driveshaft must operate through constantly changing angles between the transmission and axle. High quality steel (Steel SM45) is a common material for construction. Steel drive shafts are usually manufactured in two pieces to increase the fundamental bending natural frequency because the bending natural frequency of a shaft is inversely Proportional to the square of beam length and Proportional to the square root of specific modulus. The two piece steel drive shaft consists of three universal joints, a cross centre supporting bearing and a bracket, which increase the total weight of a vehicle. Power transmission can be improved through the reduction of inertial mass and light Hook's weight. Substituting composite structures for conventional is metallic structures has many advantages because of higher specific stiffness and higher specific strength of composite materials. Composite materials can be tailored to efficiently meet the design requirements of strength, stiffness and composite drive shafts weight less than steel or aluminium of similar strength. It is possible to manufacture one piece of composite. Drive shaft to eliminate all of the assembly connecting two piece steel drive shaft. Also, composite materials typically have a lower modulus of elasticity. As a result, when torque peaks occur in the driveline, the driveshaft can act as a shock absorber and decrease stress on part of the drive train extending life. Many researchers have been investigated about hybrid drive shafts and Joining methods of the hybrid shafts to the yokes of universal Joints. But this project provides the analysis of the design in many aspects. The advanced composite materials such as Graphite, Carbon, Kevlar and Glass with suitable resins are widely used because of their high specific strength (strength/density) and high specific modulus (modulus/density).Advanced composite materials seem ideally suited for long, power driver shaft (propeller shaft) applications. Their elastic properties can be tailored to increase the torque they can carry as well as the rotational speed at which they operate. The drive shafts are used in automotive, aircraft and aerospace applications. The automotive industry is exploiting composite material technology for structural components construction in order to obtain the reduction of the weight without decrease in vehicle quality and reliability. It is known that energy conservation is one of the most important objectives. In vehicle design and reduction of weight is one of the most effective measures to obtain this result. Actually, there is almost a direct proportionality between the weight of a vehicle and its fuel Consumption, particularly in city driving.

II. REVIEW WORK

The term drive shaft first appeared during the mid-19th century. In Storer's 1861 patent reissue for a planning and matching machine, the term is used to refer to the belt-driven shaft by which the machine is driven. The term is not used in his original patent. Another early use of the term occurs in the 1861 patent reissue for the Watkins and Bryson horse-drawn mowing machine. Here, the term refers to the shaft transmitting power from the machine's wheels to the gear train that works the cutting mechanism.

The first application of composite drive shafts to automobiles was developed by Spicer U-joint divisions of the Dana Corporation for the Ford Econoline van models in 1985 [3].

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Hargude, et.al [1] In this paper the author carried out experiments to investigate maximum torque, buckling torque transmission and critical speed of composite drive shaft. In this paper it is investigated the composite material which will replace the conventional steel shaft. The composite structures such as carbon/Epoxy and Glass/Epoxy 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.

Badie, et.al [2] In this paper it is mentioned that 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. To carry out this work FEA method are used.

Dharmadhikari, et.al [3]In this paper review of optimization of drive shaft using the Genetic Algorithm and ANSYS.

Bankar, et.al [4]In this paper it is mentioned that replace a two-piece metallic drive shaft by a composite drive shaft. The following materials can be chosen as Steel, Boron/Epoxy Composite, Kevlar/Epoxy Composite, Aluminum – Glass/Epoxy Hybrid, 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.

Badie [5], In this paper it is mentioned that 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) 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.

Khoshravan, et. al. [6] In this paper it is mentioned that design method and vibrational analysis of composite propeller shafts. Designing of a composite drive shaft is divided in two main sections design of the composite shaft and design of couplings. In composite shaft design some parameters such as critical speed, static torque and adhesive joints are studied, the behaviour of materials is considered nonlinear isotropic for adhesive, linear isotropic for metal and orthotropic for composite shaft. Along with the design all the analyses are performed using finite element software (ANSYS). The results show significant points about optimum design of composite drive shafts.

Sivaprsad et.al. [7]In this paper it is mentioned that the modelling and analysis of composite drive shaft by replacing the conventional stainless steel with composite materials. The materials which use in this analysis were E-glass epoxy, high strength carbon epoxy, and high modulus carbon epoxy. Conventional drive shaft is a two piece steel drive shaft in order to make it as a single long continuous shaft we are using composite materials. Static, model and buckling analysis on these materials is done by using ANSYS software.

Mutasher [9]In this paper it is shows that t determined 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 analyse the hybrid shaft under static torsion. Dr. Andrew Pollard GKN Technology, Wolverhampton, UK has been delivering carbon composite propeller shafts to production car applications since 1988. The technical drivers for use of composite material in this application are very powerful; the weight saving in particular can be considerable. Despite this, the overwhelming majority of automotive propeller shafts continue to be produced from steel. [1].

The Renault E space Quadra, launched in 1988, was the pioneering application for composite propeller shafts in production vehicles. A one-piece composite shaft was specified, in place of the alternative two-piece steel shaft solution. The majority of Renault E space production was front wheel drive vehicles; use of a composite shaft for the four wheel drive versions reduced the engineering modifications required for the floor pan. The floor was in any case sensitive to noise and vibration inputs, which were improved by the absence of a propeller shaft centre support bearing. The composite propeller shaft system weighed 5kg, compared to10 kg for the two-piece steel alternative. The vehicle remained in production until 1996, at which time the Quadra version was deleted from the product range.

Dai Gil Lee et. al. (2003) [10], Study by substituting hybrid aluminium composite structures for conventional metallic structures has many advantages because of higher stiffness and higher specific strength of composite materials. In this work, one piece automotive hybrid aluminium/composite drive shaft was developed with a new manufacturing method, in which a carbon fiber 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 aluminium tube and the composite layer calculated by finite element analysis. Press fitting method for the joining of the aluminium/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 aluminium/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.

E. Sevkatet. al.(2013)[11], In this research paper, hybrid aluminium shafts were manufactured and tested. Their torsional properties were investigated. To see influence of the hybrid aluminium/composite interface properties on the torsional properties of hybrid aluminum/composite tubes; four different surface treatment on aluminum were applied. One aluminium was kept as purchased, second one sanded longitudinally, third one was knurled and last one was hole drilled. Then composite layer were designed using Composite Designer software. The fibers were wound on aluminium tubes at 45^o using filament winding machine. Filament winding machine was equipped with resin bath and fiber tension system as well as fiber storing shelf system. Hybrid materials having high specific stiffness and strength, excellent fatigue properties, corrosion resistance and increased natural bending frequencies; they are used in many applications. One of the applications of hybrid aluminium/composite tubes is using them as a driveshaft for automotive industry.

M.A. Badie (2010) [12]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 $0^0$to 90^0 On the other hand, the critical buckling torque has a peak value at 90^0 and lowest at a range of 20^0-$40^0$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 $\pm45^0$experience higher load carrying capacity and higher torsional stiffness. Specimens of carbon/epoxy or glass/epoxy composites with fiber orientation angles of $\pm45^0$ show catastrophic failure mode. In a hybrid of both materials, [$\pm45^0$] configuration influenced the failure mode.

Charles W. Bert et. al. (1995) [13], In this paper it is mentioned that laminated composite, circular cylindrical hollow shafts are used extensively as primary load-carrying structures in many applications under various loading configurations. Advanced composite materials also seem ideally suited for long, power drive-shaft applications. At the same time, from a design point of view, local and general instability arising from the action of torsional loads often represents the limiting load condition. In the present study, a theoretical analysis is presented for determining the buckling torque of a circular cylindrical hollow shaft with layers of arbitrarily laminated composite materials by means of various thin-shell theories. Comparisons with previous investigations are listed for isotropic and arbitrarily laminated composite material drive shafts.

Y. A. Khalid (2005) [14] throughout the experimental study by author, a bending fatigue analysis was carried out for hybrid aluminum/composite drive shafts. The hybrid shafts used were fabricated using filament winding technique. Glass fiber with a matrix of epoxy resin and hardener were used to construct the external composite layers needed. Four cases were studied using aluminum tube wounded by different layers of composite materials and different stacking sequence or fiber orientation angles. The failure mode for all the hybrid shafts was identified. The macroscopic level tests indicate that the cracks initiating in the zones free of fibers or in the outer skin of resin and increase with increasing number of cycles until the failure of specimen. It has also been noticed that there is no fiber breakage from the rotating bending fatigue test. Results obtained from this study show that increasing the number of layers would enhance the fatigue strength of aluminum tube up to 40%, for [±45].

Robert S. Salzaret. al. (1998) [15], this paper demonstrates a logical step in the application of fiber-reinforced composites is to take advantage of their light-weight/high-strength potential and replace traditional monolithic shaft designs with composite materials. In the case of aircraft engine shafts where the high-temperature environment excludes the use of most traditional materials, a high-strength titanium alloy is recommended. The feasibility of using lighter-weight/stronger composite shafts, as well as the complexity of the design problem, along with the careful consideration of practicality that must be taken prior to the abandonment of traditional monolithic designs in highly critical applications.

III. CONCLUSION

From this extensive survey of various research we have concluded that for replacement of conventional steel drive shaft by composite material drive shaft it is necessary to build the economical manufacturing system and increase the manufacturing durability as we have seen the lot of difficulty due to manufacturing problems. Lot of research is by software and analytical but the practical experimentation is very much far due to manufacturing difficulties.

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