Design and Analysis of Composite Drive Shaft- A Review

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Abstract— Polymeric materials reinforced with synthetic fibres such as glass, carbon, and aramid provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials, i.e. wood, concrete, and steel. Despite these advantages, the widespread use of synthetic fibre-reinforced polymer composite has a tendency to decline because of their high-initial costs, their use in non-efficient structural forms and most importantly their adverse environmental impact. 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. The overall objective of this work is to analyze a composite drive shaft for power transmission. This work deals with the replacement of conventional steel drive shafts composite drive shaft for an automotive application.

Key words: Automotive, Composite, Cost, Drive Shaft, Fiber, Weight

I. INTRODUCTION

Over the last thirty years composite materials, Plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The most widely used meaning is the following one, which has been stated by Jartiz "Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form".

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 center 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. The application of composite materials started first at the aerospace industry in 1970s, but nowadays after only three decades, it has been developed in most industries. Meanwhile, the automotive industry, considered as a pioneer in every country, has been benefited from the properties and characteristics of these advanced materials For automotive applications, the first composite drive shaft was developed by the Spicer U-Joint division of Dana Corporation for Ford econoline van models in 1985 [1]. 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.

II. LITERATURE SURVEY

Dai Gil Lee, Hak Sung Kim, Jong Woon Kim and Jin Kook Kim [2] use hybrid aluminum/composite for making automotive drive shaft. In this work, one-piece automotive hybrid aluminum/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 aluminum tube rather than wrapping on the outer surface to prevent the composite layer from being damaged by external impact and absorption of moisture. 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.

Bhirud Pankaj Prakash and Bimlesh Kumar Sinha [3] use Kevlar/epoxy or E glass polythene resin composite automotive drive shaft. The intention of work is to minimize the weight of drive shaft. In this work an attempt has been to estimate the deflection, stresses, and natural frequencies under subjected loads using FEA. Further comparison carried out for both loads using FEA. Further comparison carried out for both optimized and stress intensity factor found for both Steel and composite drive shafts. The presented work was aimed to reduce the fuel consumption of the automobile in the particular or any machine, which employs drive shafts; in general it is achieved by using light weight composites like Kevlar/Epoxy. By taking into considerations the weight saving, deformation, shear stress induced and resonant Frequencies it is evident that Kevlar/Epoxy composite has the most encouraging properties to act as replacement for steel out of the considered two materials.

Sagar R dharmadhikari, sachin G mahakalkar, jayant P giri and nilesh D khutafale [4] work on Design of composite drive shaft, Analysis of composite drive shaft using ANSYS, Design optimization using genetic algorithm (GA) by Modeling and simulation. In this they found that the replacement of conventional drive shaft results in reduction in weight of automobile. The finite element analysis is used in this work to predict the deformation of shaft. The deflection of steel, HS carbon / epoxy and HM carbon / epoxy shafts was 0.00016618, 0.00032761 and 0.0003261 mm respectively. The frequency calculated by bernoulli – euler theory is high because it neglects the effect of rotary inertia & transverse shear. Hence the single piece high strength carbon / epoxy composite drive shaft has been proposed to design to replace the two piece conventional steel drive shaft of an automobile.

M.R. Khoshravan and A. Paykani [5] work on Design of a composite drive shaft, Modal analysis of composite drive shaft using ANSYS, The weight comparison between composite and steel drive shafts Modeling and simulation. In this they found that Mechanical properties for each Lamina of the laminate. Load carrying capacity, lateral bending natural frequency lateral bending natural frequency, buckling torque, effect of fiber angle.

R. P. Kumar Rompicharla and Dr. K. Rambabu [6] use Kevlar /Epoxy composite material and The drive shaft of Toyota Qualis was chosen for determining the dimensions, which were used then used for the material properties of composites were used the stability of drive shaft is ensured by limiting the include values with in the permissible range in ANSYS 12.0. The stress intensity value at crack tip is observed for composite driveshaft is low.

D.dinesh and F. anand raju [7] work on optimum design and analysis of a composite drive shaft for an automobile by using genetic algorithm and ANSYS. In this they found that the deflection of steel, e – glass/ epoxy, high strength carbon/epoxy and high modulus carbon/epoxy shafts were equal to 0.012407, 0.025262, 0.019288 and 0.012919 mm respectively. The fundamental natural frequency of steel, e – glass/ epoxy, high strength carbon/epoxy and high modulus carbon/ epoxy shafts were 9319.98, 6514.56, 7495.42 and 9270.28 rpm respectively. The torsional buckling capacity of steel, e – glass/epoxy, high strength carbon/ epoxy and high modulus carbon/epoxy shafts were 43857.96, 29856.45, 3772.11 and 3765.75 n-m respectively.

Bhushan K. Suryawanshi and Prajitsen G.Damle [8] presented work on hybrid aluminium/composite drive shaft and found that a press fit joining method between the steel yoke with protrusions on its surface and the aluminium tube was developed to increase the reliability of joining and to reduce manufacturing cost.

Harshal Bankar, Viraj Shinde and P. Baskar [9] chose 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. The stress distribution and the maximum deformation in the shaft are the functions of the stacking of material. The optimum stacking of material layers can be used as the effective tool to reduce weight and stress acting on the drive shaft.

M.A.K. Chowdhuri and R.A. Hossain [10] proposed two different designs are, one is purely from Graphite/Epoxy lamina and other is using Aluminum with Graphite/Epoxy. The basic requirements considered here are torsional strength, torsional buckling and bending natural frequency. An optimum design of the draft shaft is done, which is cheapest and lightest but meets all of the above load requirements. Progressive failure analysis of the selected design is also done.

V. S. Bhajantri, S. C. Bajantri, A. M. Shindolkar and S. S. Amarapure [11] use Carbon Epoxy Composite automotive drive shaft. The design procedure is studied and along with finite element analysis some important parameter are obtained. The composite drive shaft made up of HM carbon / epoxy multilayered composites has been designed. The results reveal that the orientation of fibres has great influence on the static characteristics of the composite shafts and offers advantages such as Lower weight, Higher strength, Progressive failure mechanism (offers warning before failure) , Lower power consumption.

Arun Ravi [12] uses HS Carbon/Epoxy and HM Carbon/ Epoxy Composite automotive drive shaft and analyses it by using ANSYS. . In this he found that the weight savings of the HS Carbon is 24 %(100-50 & Solid) compared to same dimensions of steel shaft and the deflection of Steel and High Strength Carbon.

Ghatage K.D and Hargude N.V [13] optimize design of automotive composite drive shaft with genetic algorithm as optimization tool. About 15.75% weight saving is achieved with Glass-carbon/Epoxy composite shaft with increase in critical speed enabling manufacturing of shaft of length 1.7 m to 2m; as compared to steel shaft; by experimentation. The results reveal that the orientation of fibers has great influence on the dynamic characteristics of the composite material shafts in a positive direction. Genetic Algorithm is suggested as an effective optimization tool.

R. Srinivasa Moorthy, Yonas Mitiku and K. Sridhar [14] design automobile driveshaft using carbon/epoxy and kevlar/epoxy composites. This work relies purely upon analytical calculations and use of ply distribution tables/graphs pertaining to 60% volume fraction and 0.13 mm ply thickness. This approach throws light upon ply distribution in standard orientations of 0º, 90º, +45º and -45º for the composite considered. The effect of varying ply staking sequence on the performance of composites can be found by using computational software. Moreover, considering the material and manufacturing cost will give better grounds to compare the overall efficacy, thus resulting in an appropriate selection of the best fibre/matrix combination for making automotive driveshaft.

Parshuram D and Sunil Mangsetty [15] Design and Analysis Composite/Hybrid Drive Shaft for Automotive. 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 automotive. In this work an attempt has been to estimate deflection, stresses under subjected loads & natural frequencies using FEA.

Sl.no	Property	Symbol	Unit	Carbon/Epoxy	Aluminum	Crowfoot satin woven glass fiber epoxy	Steel	E glass polyester resin	Kevlar / Epoxy	Boron/epoxy

1	Longitudinal modulus	E11	Gpa	190	72.0	35.5	207.0	34	95.71	169.6
2	Transverse modulus	E22	Gpa	7.7	72.0	17.2		6.53	10.45	7.29
3	Shear modulus	G12	Gpa	4.2	27.0	3.5	80.0	2.433	25.08	4.625
4	Poisson's ratio	Y	-----	0.3	0.33	0.22	0.3	0.287	0.34	0.29
5	Density	P	Kg/m3	1600	2700	2050	7600	2100	1402	2100
6	Longitudinal tensile strength	St1	Mpa	870	270	600	370			
7	Transverse tensile strength	St2	Mpa	540		700				
8	Shear strength	Ss	Mpa	30	200	60	275	420		
9	Frequency		Hz	169.64		156.5	3.76	1.238	2.04	92.72
10	Mass reduction		(%)	72		25	0	29	24	29
11	Deflection		Mm	0.3276			0.546	17.38	7.49	9.039
12	Stress		Mpa	143.7			58.59	50.05	48.56	54.118
	Paper no.			4,7,11,12	8,10,15	2	All	3	6,14	9

Table 1: Findings from Literature

III. CONCLUSION

By studying all above publish paper we found the following conclusions:

1) A two-piece steel drive shaft was considered to be replaced by a one-piece composite drive shaft.
2) The usage of composite materials has resulted in considerable amount of weight saving in the range of 81% to72% when compared to conventional steel drive shaft.
3) Apart from being lightweight, the use of composites also ensures less noise and vibration.
4) Shaft with increase in critical speed enabling manufacturing of shaft of length 1.7 m to 2m; as compared to steel shaft; by experimentation.
5) The results reveal that the orientation of fibers has great influence on the dynamic characteristics of the composite material shafts in a positive direction.
6) Genetic Algorithm is suggested as an effective optimization tool.
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 be reducing the torque transmission capacity of the shaft.
8) Natural frequency using Bernoulli – Euler and Timoshenko beam theories was compared. The frequency calculated by using the Bernoulli Euler beam theory is high, because it neglects the effect of rotary inertia & transverse shear.

IV. FUTURE SCOPE

1) This study leaves wide scope for future investigations. It can be extended to newer composites using other reinforcing phases and the resulting experimental findings can be similarly analyzed.
2) Tribological evaluation of glass/carbon fiber reinforced epoxy resin composite has been a much less studied area. There is a very wide scope for future scholars to explore this area of research. Many other aspects of this problem like effect of fiber orientation, loading pattern, weight fraction of ceramic fillers on wear response of such composites require further investigation

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