ANALYSIS OF DRIVE 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. The overall objective of this work is to analyze a composite drive shaft for power transmission. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This work deals with the replacement of conventional steel drive shafts with an Kevlar/epoxy or E glass polythene resin composite drive shaft for an automotive application. The intention of work is to minimize the weight of drive shaft. In this present work an attempt has been to estimate the deflection, stresses, and natural frequencies under subjected loads using FEA (Ansys). Further comparison carried out for both optimized and stress intensity factor found for both Steel and composite drive shafts.

Keywords: Conventional shaft, drive shaft, composite shaft, composite material, analysis, ansys etc.

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 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. 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 aluminum 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. LITERATURE REVIEW

Nowadays, composite materials are used in large volume in various engineering structures including spacecraft’s, automobiles, boats, sports’ equipment, bridges and buildings. Widespread use of composite materials in industry is due to the good characteristics of its strength to density and hardness to density. The possibility of increase in these characteristics using the latest technology and various manufacturing methods has raised application range of these materials. Drive shafts are usually made of solid or hollow tube of steel or aluminum. Over than 70% of single or two-piece differentials are made of several piece propeller shaft that result in a rather heavy drive shaft Composite drive shafts were begun to be used in bulk in automotives since 1988. The graphite/carbon/fiberglass/aluminum driveshaft tube
was developed as a direct response to industry demand for greater performance and efficiency in light trucks, vans and high performance automobiles. The main reason for this was significant saving in weight of drive shaft; the results showed that the final composite drive shaft has amass of about 2.7 kg, while this amount for steel drive shaft is about 10 kg. The use of composite drive shafts in race cars has gained great attention in recent decades. When a steel drive shaft breaks, its components, are thrown in all directions such as balls, it is also possible that the drive shaft makes a hole in the ground and throw the car into the air. But when a composite drive shaft breaks, it is divided into fine fibers that do not have any danger for the driver. Numerous studies have been carried out to investigate the optimal design and analysis of composite drive shafts with different materials and layers orientation. C. Sivakandhan & P. sureshprabhu studied that the epoxy/glass fibre composite can be employed in the drive shaft. Moreover, author believes that the real ANSYS analysis should be done to verify the stability of developed composite material under the proposed concept. The usage of composite materials and optimization techniques has resulted in considerable amount of weight saving when compared to conventional steel drive shaft. These results are encouraging and suggest that glass/epoxy composite materials effectively used in engineering applications. Pollard [2] studied different applications of composite drive shafts for automotive applications. He compared the advantages and disadvantages of them at various conditions. Rangaswamy and et al. [3] optimized and analyzed an onepiece composite drive shaft using genetic algorithm and ANSYS. They found that the use of composite materials lead to the significant reduction in weight compared to steel drive shaft. They also reported that the fiber orientation of a composite shaft strongly affects the buckling torque. Rangaswamy & Vijayarangan have investigated the manufacturing of composite shafts for automotive applications. The composite shaft is expected to transmit certain amount of torque, hence should have a certain torque capability. A factor of safety of 2 is chosen and three different materials are investigated. Due to their high length/diameter ratio, the torsional buckling capability of the shafts Composite Drive Shaft is a Good Strength and Weight Saving to Compare Conventional Materials Design and Analysis of E Glass/Epoxi Composite Drive Shaft for Automotive Applications Rastogi implemented a FEA approach to design and analyze a composite drive shaft in different conditions is also studied both experimentally and with ANSYS modeling. In the present work an effort has been made to design a HM-Carbon/Epoxi composite drive shaft. A onepiece composite drive shaft for rear wheel drive automotive application is designed and analyzed using ANSYS software. Since performance of conventional drive shafts can be severely limited by the critical speed and large mass inertia moment of metal shaft, it was investigated in the second part of the paper. Thomson [4] has discussed mechanical properties of a sandwich composites containing interfacial cracks or impact damage when loaded edgewise compression, flexure or shear. The implication of these findings on the structural integrity of mine hunting ship made from GFRP/PVC foam sandwich composite is discussed. Potluri et al., [5] have investigated stitch bonded sandwich structures of close cellular core and woven broadcloth. The stiffness of the sandwich panels, up to the top skin failure increases with increase in stitch density. Kim et al., [6] has studied the failure mode and energy absorption capabilities of different kinds of circular tubes made of carbon, Kevlar, and carbon – Kevlar hybrid fibers composite with epoxy resin. Based on the linear regression analysis results, the crushing parameters generally showed good correlation with compressive strength and shear modulus.

III. AIM AND SCOPE OF THE WORK

This work deals with the analysis of conventional steel shaft and composite shaft. Results proves that how beneficial is the replacement of a conventional steel drive shaft with E-Glass/ Epoxy glass polyester resin, Kevlar/Epoxy composite drive shafts for an automobile application. To estimate the deflection, stresses, natural frequencies under loads using ANSYS. This present work an attempt has been to estimate the deflection, stresses, natural frequencies under subjected loads using FEA. Further comparison carried out for both conventional and composite shaft

IV. DEMERITS OF A CONVENTIONAL DRIVE SHAFT

1. They have less specific modulus and strength
2. Increased weight
3. Conventional 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. Therefore the steel drive shaft is made in two sections connected by a support Structure, bearings and U-joints and hence overall weight of assembly will be more.
4. Its corrosion resistance is less as compared with composite materials.
5. Steel drive shafts have less damping capacity.

V. PURPOSE OF THE DRIVE SHAFT

1. It must transmit torque from the transmission to the differential gear box
2. The drive shaft must also be capable of rotating at the very fast speed required by the vehicle.
3. The drive shaft must also operate through constantly changing the angles between the transmission, the differential and the axles.
4. The length of the drive shaft must also be capable of changing while transmitting torque.

VI. MERITS OF COMPOSITE DRIVE SHAFT

1. They have high specific modulus and strength.
2. Reduced weights.
3. The fundamental natural frequency of the carbon fiber composite drive shaft can be twice as high as that of steel or aluminum because the carbon fiber composite material has more than 4 times the specific stiffness of steel or aluminum, which makes it possible to manufacture the drive shaft of passenger cars in one piece. A one-piece composite shaft can be manufactured so as to satisfy the vibration requirements. This eliminates all the assembly, connecting the two piece steel shafts and thus minimizes the overall weight, Vibrations and the total cost.
4. Due to the weight reduction, fuel consumption will be reduced
5. They have high damping capacity hence they produce less vibration and noise
6. They have good corrosion resistance
7. Greater torque capacities than steel or aluminum shaft
8. Longer fatigue life than steel or aluminum shaft
9. Lower rotating weight transmits more of available power

VII. DESIGN CALCULATION

Steel and composite materials and weight of the shaft is optimized and stress intensity factor found for both Steel and composite drive shafts.

7.1 Theoretical and Ansys results simulation

the drive shaft for simplicity has been first idealized as a hollow cylindrical shaft which is fixed at one end and on other end which a torque of 151Nm is applied as represented below

Fig 1: Shaft with torsional load For the the hallow shaft,

For the the hallow shaft,
let , Where Ro-Outer Radius of shaft
Ri- Inner Radius of shaft ,  L= Length of the shaft
E= Young's modulus of steel (SM45C) .
T=Applied torque
ML²
Deflection = Ymax= -------
2EI
Maximum Deflection is calculated by following formula
Max. Deflection= TX (d²/2) / I
Maximum shear stress is calculated by following formula
Max. Shear Stress = (T x Ro)/J

7.2 Fundamental natural frequency:

Drive shaft is idealized as a simply supported beam. If exact fundamental deflection (the first mode) assumed. The fundamental frequency found will be correct one; it is natural because there is no force and damping applied on the structure. When an oscillation motion repeated in equal intervals of time t, its reciprocal f=1/t, is called frequency. The bending natural frequency in composite tube is fn =

\[
\frac{\pi \sqrt{E x I}}{ML^4}
\]

Where, m – is the mass per unit length. The lateral natural frequency directly related to the lateral (Ex .I) of the drive shaft and since the moment of inertia ( I) is only determined by the geometry, then the composite drive shaft can be designed to have higher lateral frequency by increasing the modulus Ex.

7.3 Torsional Frequency:

The torsional frequency is directly related to the torsional stiffness (T/Ø), where Ø, is angle of twist and T is applied torque. The frequency of torsional vibration can be

Presented as: ft = 1/

K, being the torsional spring rate, is equal to the torsional stiffness. Im is the mass moment of inertia at propeller. For the given geometry of a drive shaft, the torsional stiffness is directly related to the modulus of rigidity (G xy) as follows, where T/Ø=Gxy/J/L, is the polar moment of inertia and L is the length. The shear modulus can be tailored to its maximum value by orienting the fibers at an angle equal to 45°. This shear modulus can be directly obtain from the extensional stiffness matrix [A] by dividing the shear stiffness Component A66 by the total thickness of the drive shaft as follows,

Gxy = A66/t

The practical application of torsion vibration system is engines. This engines have damping (source of dissipation of energy) in the crank shaft (hysteresis damping) and in inertia (damping in torsional vibration dampers and in propellers) since damping presents in normally small in magnitude for the determining the natural frequency is ignored.
7.4 Torsional Stress:
When a uniform circular shaft is subjected to a torque, it can be shown that every section of the shaft is subjected to a state of pure shear (Fig. 6.1), the moment of resistance developed by the shear stresses being everywhere equal to the magnitude, and opposite in sense, to the applied torque.

\[ T/I = G \theta /L = f \frac{s}{R} \]

7.5 Lay-up selection:
It is well known that the shear modulus of main fibers – Reinforced composites is lower than that for steel. Thus for an equivalent torsional stiffness, a fiber reinforced composite tube must have either a larger diameter or greater thickness than a steel tube. Among the various laminate configuration (+/-45) s, laminates the possess the highest shear modulus and are the primary laminate type is used in purely torsional application. To meet the minimum resonance frequency, the shaft must have and adequate axial modulus and since the axial modulus of a (+/-45) laminate is rather low, 0° layer must be added to the lay up the improve the resonance frequency. The easiest way to increase the critical buckling torque would be to increase D22 which is achieved by adding one or more 90° plies on both sides of the laminate mid plane. Therefore, the layup selected consists of +/-45° glass fiber layers 0° carbon layer and 90° glass layer at outside surface.

7.6 Analysis of Composite Drive Shaft
The finite element method is a powerful numerical tool widely used to solve nonlinear problems of elasticity, solids and structures. In this project, modeling was performed using the commercial code ANSYS. The finite element modeling’s based on a 3D element. The element retained in the ANSYS code is identified as SOLID 95; it contains 20 nodes with three degrees of freedom per node corresponding to displacements in the x, y and z directions. The shafts used in the study have different orientation of ply, all of them proved to have high buckling torque and satisfactory critical speed well over the required value. And the adhesively bonded joint has the capability to transmit the applied torque. The modeling of laminated beams using finite elements requires a much greater number of elements than simple beams. The large number of elements necessary through the thickness usually demands that a high degree of discretization also be applied in the other directions.

**METHODOLOGY**
To meet the stringent design requirement, a shaft has to be design. In this work, we will compare the conventional steel shaft with the composite shaft with various material like Boron /epoxy, kevler /epoxy E glass polyester resin will be analyses at +/- 45 degrees ply orientation. The material properties of all material considered from design consideration. The analysis will be carried out using ANSYS 12.0 OR 13.0.

The first steel (SM45C) which is to be used for reference purpose.
Composite material: Boron/Epoxy,
Kevlar/Epoxy
E Glass polyester resin.

The methodology as per follows:
1) The specification of shaft for its loading and operating conditions.
2) Obtaining 2D Drawing and loading conditions from design specifications.
3) Obtaining boundary conditions required for analysis.
4) Preparation 3D Finite element model Using HYPERMESH.
5) The above hyper mesh model analyses in ANSYS 12.0 OR 13.0

A Comparison between the results obtained from Theoretical calculation and the result taken from ANSYS 12.0 & concluded.
RESULT

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Material/Parameters</th>
<th>Deflection</th>
<th>Natural Frequency (Hz)</th>
<th>Torsional Stress (N/mm²)</th>
<th>Weight Reduction in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steel</td>
<td>0.546</td>
<td>3.76</td>
<td>58.59</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>CH/Kevlar/Epoxy</td>
<td>7.49</td>
<td>2.04</td>
<td>48.56</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>E glass Polyester resin</td>
<td>17.38</td>
<td>1.238</td>
<td>50.05</td>
<td>29</td>
</tr>
</tbody>
</table>
CONCLUSION

1) The usage of composite material has resulted to inconsiderable amount of weight saving in the range of 24-29% when compared to conventional steel shaft.

2) 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.

3) 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.

4) The presented work also deals with design optimization i.e converting two piece drive shaft (conventional steel shaft) in to single piece light weighted composite drive shaft.

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