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A Review Design Analysis And Development of Drive Shaft For Automobile Application With Optimization After Design Includes Weight Reduction

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Abstract

The automotive sector is always looking for ways to improve the performance, safety, and efficiency of vehicles. The drive shaft, which transmits torque from the engine to the wheels, is essential to accomplishing these goals. Due to their strength and longevity, conventional metallic drive shafts have long been the preferred option. They do, however, have certain disadvantages, including weight, corrosion susceptibility, and restricted design flexibility. Progress in material science has spurred investigation into composite alternatives as a response to these issues. A thorough selection of composite materials is required during the design phase, taking into account attributes including weight, strength, stiffness, and durability. All design process will be performed with aid of FE analysis using ANSYS software. Optimization will be followed after performing design which includes weight reduction of drive shaft and material selection. It has been observed from results of study that by using composite material in place of steel material, weight reduction of up to about 80% is obtained. When study is carried out for different epoxy materials of composites, it has been observed that Kevlar/Epoxy composite has proved maximum strength compared to the others. When study has been carried out for different fiber angles for composite layers, it has been observed that 900 angle of fibers is providing better fundamental frequency compared to other angles.

INTRODUCTION

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. This work deals with the replacement of a conventional steel drive shaft with E-Glass/ Epoxy, High Strength Carbon/Epoxy composite drive shafts for an automobile application.

LITERATURE REVIEW

[1] C. Sivakandhan and P. Suresh Prabhu states that in the recent days, there is a huge demand for a light weight material such as fibre 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. This work deals with the replacement of conventional steel drive shafts with an E glass/epoxy composite drive shaft for an automotive application. The design parameters were optimized with the intention of minimizing the weight of composite drive shaft. The design optimization in addition showed considerable potential improvement in the performance of drive shaft.

[2] Mohammad Reza Khoshravan, Amin Paykani and Aidin Akbarzadeh presents design method and vibrational analysis of composite propeller shafts. A propeller shaft is not limited to vehicles, but in many transmission applications can be used, but in this paper, the aim is to replace a metallic drive shaft by a two-piece composite drive shaft. 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.

[3] M.A.K. Chowdhuri, R.A. Hossain states that automotive drive Shaft is a very important component of vehicle. The present paper focuses on the design of such an automotive drive shaft by composite materials. Now a days two pieces steel shaft are used as drive shaft. However, the main advantages of the present design is;only one piece of composite drive shaft is possible that fulfil all the requirements of drive shaft. Two different designs are proposed, one is purely from Graphite/Epoxy lamina and other is using Aluminium 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.Prof .Amir Khan, Sankalp Verma

[4] M. A. Badi, A. Mahd, A. R. Abutali, E. J. Abdullaand R. Yonus states that Laminated composites, with their advantage of higher specific stiffness, gained substantiality in the field of torque carrying structures through many applications. Composite drive shafts offer the potential of lighter and longer life drive train with higher critical speed. In this study, finite element analysis performed to investigate the effects of fibers winding angle and layers stacking sequence on the critical speed, critical buckling torque and fatigue resistance. A configuration of a hybrid of one layer of carbon-epoxy (0º) and three layers of glass-epoxy (±45º, 90º) was used. The results show that, in changing carbon fibers winding angle from 0º to 90º, the loss in natural frequency is 44.5% and shifting from the best to the worst stacking sequence the DS loses 46.07% of its buckling strength, which gain the major concern over shear strength in DS design. The layers of ±45º angles are to be located far at inner side and that of cross-ply configuration located at top face with the 90º layer exposed to outside to increase the fatigue resistance, that the stacking sequence has an effect on fatigue properties.

[5] Dai Gil Lee Substituting composite structures for conventional metallic structures have many advantages because of higher specific stiffness and higher specific strength of composite materials. 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. 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.

Problem Statement

Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and or not soluble in each other. The main difference between composite and an alloy are constituent materials which are insoluble in each other and the individual constituents retain those properties in the case of composites, where as in alloys, constituent materials are soluble in each other and forms a new material which has different properties from their constituents. They have high specific modulus and strength. Reduced weight. The fundamental natural frequency of the carbon fibre composite drive shaft can be twice as high as that of steel or aluminium because the carbon fibre composite material has more than 4 times the specific stiffness of steel or aluminium, which makes it possible to manufacture the drive shaft of passenger cars in one piece. A one-piece composite shaft cans 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. Due to the weight reduction, fuel consumption will be reduced. They have high damping capacity hence they produce less vibration and noise. They have good corrosion resistance. Greater torque capacities than steel or aluminium shaft. Longer fatigue lives than steel or aluminium shaft. Lower rotating weights transmit more of available power

OBJECTIVE

1. **Performance Enhancement:**
   The primary objective is to improve the performance of the drive shaft in terms of torque transmission, power delivery, and efficiency. This includes minimizing energy losses due to friction, vibration, or misalignment.

2. **Reliability and Durability:**
   Ensuring the drive shaft can withstand the expected operating conditions without premature failure is crucial. This involves selecting appropriate materials, optimizing the design to withstand anticipated loads, and conducting rigorous testing to validate performance.

3. **Weight Reduction:**
   In applications where weight is a critical factor, such as automotive or aerospace engineering, optimizing the drive shaft's weight without sacrificing strength and stiffness can lead to improved fuel efficiency, vehicle dynamics, or payload capacity.

4. **Integration with System Components:**
   Ensuring compatibility and seamless integration with other system components, such as gears, bearings, and couplings, is essential for optimal performance and reliability of the overall system.

5. **Optimal Design Parameters:**
   Utilizing advanced simulation and optimization techniques to identify the most suitable design parameters, such as shaft diameter, length, wall thickness, and material properties, can help achieve the desired performance objectives while minimizing weight and cost.

6. A one-piece composite drive shaft for rear wheel drive automobile was designed optimally by using Genetic Algorithms for E-glass/epoxy and HM-carbon/epoxy composites with the objective of minimization of weight of the shaft which is subjected to the constraints such as torque transmission, torsional buckling strength capabilities and natural bending frequency.

7. A solid three dimensional CAD model created by Pro-E software

8. Structural and Buckling Analysis is carried out using ANSYS software

DESIGN OPTIMIZATION

Optimization of an engineering design is an improvement of a proposed design that results in the best properties for minimum weight. Most of the methods used for design optimization assume that the design variables are continuous. In structural optimization, almost all design variables are discrete. A simple Genetic Algorithm (GA) is used to obtain the optimal number of layers, thickness of ply. All the design variables are discrete in nature and easily handled by Genetic Algorithm (GA).
A simple genetic algorithm that yields good results in many practical problems is composed of three operators: [2]
l. Reproduction
2. Crossover
3. Mutation
Reproduction is a process in which individual strings are copied according to their objective

function values, f (biologists call this function the fitness function). Intuitively, we can think of the function f as some measure of profit, utility, or goodness that we want to maximize. Copying strings according to their fitness values means that strings with a higher value have a higher probability of contributing one or more offspring in the next generation. This operator, of course, is an artificial version of natural selection, a Darwinian survival of the fittest among string creatures. In natural populations fitness is determined by a creature's ability to survive predators, pestilence, and the other obstacles to adult-hood and subsequent reproduction. In our unabashedly artificial setting, the objective function is the final arbiter of the string-creatures life or death. The reproduction operator may be implemented in algorithmic form in a number of ways. Perhaps the easiest is to create a biased roulette wheel where each current string in the population has a roulette wheel slot sized in proportion to its fitness. Suppose the sample population of four strings in the black box problem has objective or fitness function values f as shown in Table 6.1 (for now we accept these values as the output of some unknown and arbitrary black box later we will examine a function and coding that generate these same values).

No.	String	Fitness	% of Total
1	01101	169	14.4
2	11000	576	49.2
3	01000	64	5.5
4	10011	361	30.9
Total		1170	100.0

Table 5.1 sample problem strings and fitness values

Summing the fitness overall four strings, we obtain a total of 1170 (The percentage of population total fitness is also shown in the table. The corresponding weighted roulette wheel for this generation's reproduction is shown in Fig. To reproduce, we simply spin the weighted roulette wheel thus defined four times. For the example problem, string number l has a fitness value of 169, which represents 14.4 percent of the total fitness. As a result, string l is given 14.4 percent of the biased roulette wheel, and each spin turns up string l with probability 0.144. Each time we require another offspring, a simple spin of the weighted roulette wheel yields the reproduction candidate. In this way more highly fit strings have a higher number of offspring in the succeeding generation. Once a string has been selected for reproduction an exact replica of the string is made. This string is then entered into a mating pool, a tentative new population, for further genetic operator action. [2]

After reproduction, simple crossover may proceed in two steps. First members of the newly reproduced strings in the mating pool are mated at random. Second, each pair of strings undergoes crossing over as follows: an integer position k along the string is selected uniformly at random between 1 and the string length less one [1,I-1]. Two new strings are created by swapping all characters between positions k + 1 and I inclusively.

STATIC ANALYSIS

Static analysis deals with the conditions of equilibrium of the bodies acted upon by forces. A static analysis can be either linear or non-linear. All types of non-linearity are allowed such as large deformations, plasticity, creep, stress stiffening, contact elements etc. This chapter focuses on static analysis. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those carried by time varying loads. A static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects. A static analysis can however include steady inertia loads such as gravity, spinning and time varying loads.

In static analysis loading and response conditions are assumed, that is the loads and the structure responses are assumed to vary slowly with respect to time. The kinds of loading that can be applied in static analysis includes,

1. Externally applied forces, moments and pressures
2. Steady state inertial forces such as gravity and spinning
3. Imposed non-zero displacements

A static analysis result of structural displacements, stresses and strains and forces in structures for components caused by loads will give a clear idea about whether the structure or components will withstand for the applied maximum forces. If the stress values obtained in this analysis crosses the allowable values it will result in the failure of the structure in the static condition it. To avoid such a failure, this analysis is necessary.

Boundary Conditions

The finite element model of Carbon/Epoxy shaft is shown in Figure End face of shaft (only one end) is fixed in all direction & rotational velocity of 6500 RPM is applied.

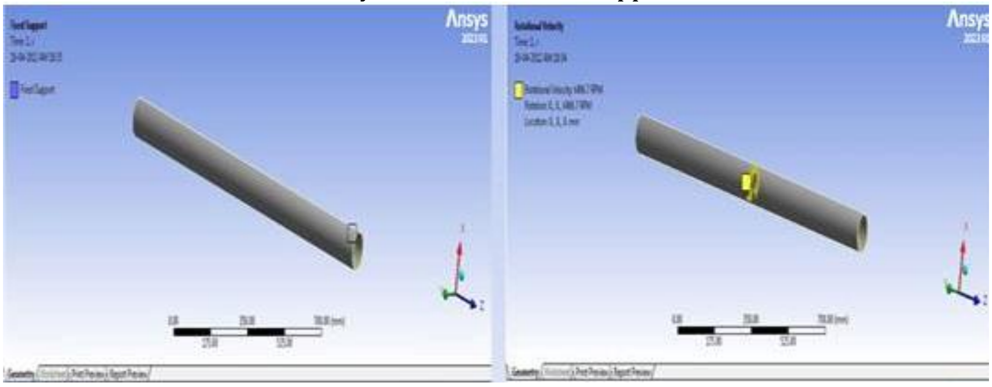

Image No 6.1 Finite element model of Carbon/Epoxy shaft

Buckling Analysis

Buckling analysis is a technique used to determine buckling loads (critical loads) at which a structure becomes unstable, and buckled mode shapes (The characteristic shape associated with a structure's buckled response).

For thin walled shafts, the failure mode under an applied torque is torsional buckling rather than material failure. For a realistic driveshaft system, improved lateral stability characteristics must be achieved together with improved torque carrying capabilities. The dominant failure mode, torsional buckling, is strongly dependent on fiber orientation angles and ply stacking sequence.

CONCLUSIONS

The study on the design and analysis genetic algorithm results with genetic algorithm tables, Graphs and final Results. Also finite element analysis results including static analysis result containing total deformation of steel shaft ,Total deformation of composite shaft, Maximum principal elastic strain of steel shaft, Maximum principal elastic strain of composite shaft, Maximum principal stress of steel shaft, Maximum principal stress of composite shaft, Maximum shear elastic strain of steel shaft, Maximum shear elastic strain of composite shaft, Maximum shear stress of steel shaft, Maximum shear stress of composite shaft, Equivalent stress of steel shaft , Equivalent stress of composite shaft. And buckling analysis result including total deformation of steel shaft, total deformation of composite shaft. Also results of finite element analysis in tabular form.

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