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Research Paper

Optimization and Experimental determination of natural frequency of Hybrid Composite Automobile Drive Shaft”

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PG Research Guide)

ABSTRACT:
In this paper, a study is focused on optimal design of hybrid composite Automobile over drive shaft for various objectives such as fundamental Natural Frequency and torsional Strength. The Work aims to maximize Maximum Torsional Strength, increases Natural Frequency with minimizing weight. Hence, taugichi optimization method is used to generate a single response for these two performance characteristics.
Also, parametric study will be carried to understand the effect of each variable on various design objectives the design variable come from geometrical properties like no. of ply, orientation angle, stacking sequences and materials. The constraint will come from state variables and manufacturing constraint. The optimization will also carry for torsional strength. With minimum weight it is shown that the introduction of new ply orientations compared to the classical 0°, ±45° and 90° plies can lead to significantly improved optimal designs.
Furthermore, Taugchi optimization of Automobile over drive shaft is carried out for fundamental natural frequency

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I. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibres, particles, or flakes. The Examples of composite systems include concrete reinforced with steel and epoxy reinforced with carbon fibres, etc.

The two piece steel drive shaft consists of three universal joints, a center supporting bearing and a bracket, which increase the total weight of a vehicle. Power transmission can beimprovedthroughthereductionofinertialmassandlightweight.Substitutingcompositestructures for conventional metallic structures has many advantages because of higher specific stiffness and higher specific strength of composite materials. Composite materials can be efficiently meet the design requirements of strength, stiffness and composite drive shafts weightless than steel or aluminum of similar strength.

It is possible to manufacture one piece of composite. The 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 driving, the drive shaft act as a shock absorber and decrease stress on part of the drivetrain extending life. Fiber reinforced polymer (FRP) composites can be simply described as multi-constituent materials that consist of reinforcing fibres embedded in a rigid polymer matrix. Many FRPs offer a combination of both strength and modulus that are either comparable to or better than many traditional metallic materials. A diverse range of polymers can be used as the matrix to FRP composites, and these are generally classified as thermoplastic (e.g. polyether-ether-ketone, polyamide) resins or thermoset (e.g. epoxy, polyester).

On the other hand, thermoset resins the most widely used matrices for advanced composites usually consist of a resin and a comparable curing agent. When they two are initially mixed they form a low viscosity liquid that cures as a result of either internally generated or externally applied heat. The curing reaction forms a series of cross links between molecular chains so that one large molecular network is formed, resulting in an intractable solid that cannot be reprocessed on reheating.

II. OPTIMIZATION OF HYBIRD COMPOSITE MATERIAL

In present era of products development composite are being used because of easy in manufacturing and low weight to volume ratio. Moreover apart from this increasing the awareness towards environmental conditioning and required more versatile materials based higher leads to filler composite materials. Taguchi's parameter design is an important tool for robust design. It offers a simple and systematic approach to optimize the design parameters because this systematic approach can significantly minimize the overall testing time and the experimental costs.

Two major tools used in robust design are signal to noise ratio (S/N), which measures quality with emphasis on variation, and orthogonal array, which accommodates many design factors simultaneously. In design of experiment, the most important stage lies in the selection of the control factors. The cost is most important than quality but quality is the best way to reduced cost.

Through exhaustive literature review on erosion behavior of polymer composites, it has been observed that factors viz., orientation angle, stacking sequences, filler materials, volume fraction and different material etc. mostly influence on the performances of polymer composites. For elaboration of experiments plan the method of Taguchi for five factors at four levels is used, being understood by levels taken by the factors. The selected parameters viz., orientation angle, stacking sequences, filler materials, volume fraction and different material are considered in this study. The control factors and the parameter settings for composite are given in Table 1

Table 1 Parameter setting for composite materials

Control Factors	Symbols	Fixed parameters	
Orientation angle	FACTOR –A	Volume fraction	50:50
Stacking sequences (layer)	FACTOR –B		
Filler materials	FACTOR –C		

The experimental observations are transformed into signal-to-noise (S/N) ratios. There are several S/N ratios available depending on the type of characteristics such as: 'Smaller-the-better' characteristic: Nominal-the-better' characteristics 'Larger-the-better' characteristics where n the number of observations, y the observed data, Y the mean and S the variance. The S/N ratio for minimum weight comes under 'smaller is better' characteristic,

As you move forward in your design, you can assess the impact that changing certain parameters can have in design. The parameter can include dimensional parameters,

The parametric optimization study allows us to, define the parameter range, specific design constraints and analyze the results.

Table .2 Levels for various control factors

Control factor	Levels			Unit
	I	II	III	
A. *Orientation angle*	0	45	90	Degree
B. *Stacking sequences (no of layer)*	1	2	3	mm
C. *Filler materials*	Carbon	Kevlar	Metal	Unit less

Table .3 Orthogonal array for L09 Taguchi Design

Sr.No.	Orientation angle	Stacking sequences (no of layer)	Filler materials
1	1	1	3
2	1	3	1
3	1	2	2
4	2	1	2
5	2	3	3
6	2	2	1
7	3	1	1
8	3	3	2

III. MANUFACTURINGANDTESTINGOFLAMINATES

The design of a laminated composite structure, such as a flat floor panel or a pressure vessel, starts with the building block of laminate, in which fibre and matrix are combined in manufacturing process such as hand lay up or filament winding. The material of the fibre and matrix, processing factors such as packing arrangements and fibre volume fraction determine the stiffness, strength of a single lamina. These properties can be found by using the properties of the individual constituents of the lamina or by experiments.

1. Selection of Matrix Material

Epoxy resin 520, Epoxy hardener-PAM. The epoxy resin and epoxy hardener were mixed in the ratio of 10:1 by the weight as suggested. The epoxy resin has the density of 1.22 g/cc. The Epoxy Resin-520and Epoxy hardener-PAM were mixed in the ratio of 10:1 by weight as suggested. Epoxy resin and hardener mixture was stirred thoroughly before fiber mats were introduced in the matrix material. Each laminate was cured under constant pressure near about 24hours in them old and further cured at room temperature at least12 hours.

Table4 Properties of Epoxy Resin520

Sr.No.	Properties	Epoxy	Units
1	Specific density	1.22	g/cc
2	Young's Modulus	3.792	Gpa
3	Ultimate Tensile Strength	82.74	Mpa

2. Material Composition in laminates

Thematerialcompositionofhybridcompositematerialwithangleorientationwithsequenceof layer according to manipulation by taguchi method in Mini-Tab software.

Table5LaminateNo.01 $[(0^0)c,(+-45^0)k,90^0]^{[13]}\ _{c2}$

Sr.No.	Composition		Size(L×B×H)mm	Quantity
	Hybrid(fiber) %	**Epoxy%**	**Tensile Testing**	
1	50	50	140×20×3	6

Sr.No.	Composition		Size(L×B×H)mm	Quantity
	Hybrid(fiber) %	**Epoxy%**	**Shear Testing**	
1	50	50	75×20×3	6
Sr.No.	**Composition**		**Size(L×B×H)mm**	**Quantity**
	Hybrid(fiber) %	**Epoxy%**	**Flexure Testing**	
1	50	50	100×13×3	6

3. Calculation of Material properties from Stress-Strain Diagram

With the help of stress-strain diagram the material properties such as young's modulus and shear modulus in longitudinal and transverse direction are calculated. Which are tabulated below: Material Properties of LaminatesinTransverseandLongitudinaldirections**laminateNo01-(CARBON+KEVLAR)**

Table6 Material Properties of Laminate

MaterialProperty	LaminateNo01			
	Trail 1	**Trial 2**	**Trail 3**	**Avg.**
Young's Modulus in Longitudinal Direction(E_1)GPa	2.502	3.337	2.201	**2.680**
Young's Modulus in Transverse Direction(E_2)GPa	2.889	2.998	2.969	**2.952**
Shear Modulus in Longitudinal Direction(G_{12})GPa	0.765	0.979	1.321	**1.021**
Shear Modulus in Transverse Direction(G_{23})GPa	1.351	1.201	1.001	**1.184**

IV. EXPERIMENTAL ANYLSIS

The block diagram and topology of an FFT analyzer are different to that of the more usual super heterodyne or sweep spectrum analyzer. In particular circuitry is required to enable the digital to analogue conversion to be made, and then for processing the signal as a Fast Fourier Transform. The FFT spectrum analyzer can be considered to comprise of a number of different blocks

Diagram:1 Experiential set up

Diagram -2 output of FFT Analyzer

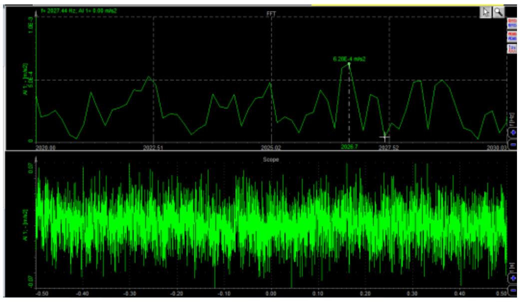

Table 7. ResultscarriedoutinFFTanalyzer

1stNatural Frequency	1298.9Hz
2ndNatural Frequency	1493.5Hz
3$^{rd.}$Natural Frequency	2059.4Hz

V. RESULTS AND DISCUSSION

The discussion on results obtained by theoretical, experimental analysis is carried out toreach the conclusion. The difference in results is compared for mass and the fundamental naturalfrequency, also the difference has been found in natural frequency by software analysis (**ANSYS15)**and experimental analysis is addressed here.

1) ComparisonbetweenAnalyticalCalculationsofSteelandHybridCompositepropellerShaft

Table8ComparisonbetweensteelandHybriddriveshaft

Parameter	**Steel shaft**	**Hybrid Composite shaft**
Outer Diameter	65 mm	65 mm
Thickness	3 mm	12 mm
Applied Torque(T)	914.3N-m	914.3N-m
Natural Frequency(f_{nb})	513.82Hz	1252Hz
Mass(m)	2.68 kg	1.118 kg
% Saving n mass	-	58.28 %

Above table its shows that the comparison between steel and composite drive shaft in which applied torque is same for steel and composite drive shaft. The Minimum requirement of natural frequency is 80 Hz which can be achieved by both steel and Composite drive shaft. Composite shafts having very low weight of1.2kgwhereassteel shaft of weight is 2.68kg

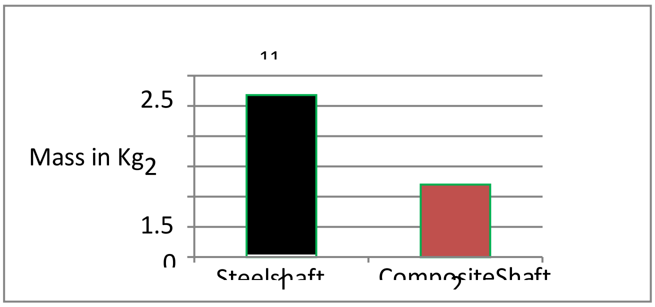

Diagram 3: Comparison between mass of Steel and hybrid composite Propeller Shaft

2) Comparison of FEA results and Experimental results for Natural frequency

Here, comparison is made between natural frequencies obtained from FEA and Experimental method for Hybrid composite material drive shaft. It is seen that Hybrid composite material driveshaft is having higher frequency.

Table9 Comparison of FEA results and experimental results for Natural frequency

Frequency	By Experimental	By FEA	%Error
1st Frequency	1298.9Hz	1259Hz	3.004
2ndFrequency	1493.5Hz	1512Hz	1.256
3rdFrequency	2059.4Hz	2152 Hz	4.32

VI. CONCLUSION

In this thesis optimization of Hybrid composite material is carried out. The work in this thesis is carried out in four parts .First parts is focused on validation of composite overdriveshaftmodelingbyFEM.Whereasinsecondparts,aparametricstudy carried out to understand the effect of each design variable on various design objectives. Optimization of composite over drive is carried out by Taguchi Technique with ANSYS. The optimization process reduced the weight, increases the natural frequency and increases torsional strength of composite material.

Finallyfiniteelementmodalanalysisiscarriedoutwithhelpof FEA.Afterthemanufacturing, its experimental modal analysis and torsion testing was performed for finding out the angle of twist.

The following conclusions are drawn from the Present work.

1) The Single objective optimization for weight is carried usingTaguchi Technique.

2) The stacking sequences 45 -0- 90 degree are the best results on performances of Automobile over drive shaft like low weight, high natural frequency and torsional strength.

3) The weight of the carbon -Kevlar propeller shaft is reduced by **58.28 %** as compared to steel propeller shaft.

4) It is found that the fiber orientation and stacking sequence of layer [**(0^0) c, (+-45k^0),90^0c]** is the optimum angle to have maximum torsion stiffness and natural frequency.

5) The natural frequencies of hybrid composite propeller shaft are increased by **55.58%, 69.70 %**and **77.66 %** by **FEA** as compared to steel shaft

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