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Design and Modal analysis of Composite Layered Shaft

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Abstract- **The Torsional vibrations are angular vibrations in an object these can be seen in a shaft along its own axis of the rotation. Torsional vibration is important concern in power transmission s using rotating shafts and couplings where it can lead to failure and the other effect of torsional vibration axis for passenger vehicle. Torsional vibration leads to noise at different speeds. In this paper a automotive shaft of Ecomet 1611 model vehicle drive shaft is chosen. The modal analysis is performed by taking Steel, E-Glass and HM Carbon layered composites materials are chosen to perform modal analysis a using Simulation Software ANSYS.**

Index terms- **ANSYS, torsional vibration, couplings, power transmission**

I.INTRODUCTION

The automobiles use a longitudinal shaft to transmit power from an engine to the other end of the vehicle before it goes to the wheels the short drive shafts are used to transmit power from the central differential, transmission to the wheels. The use of composite materials in every field is due to the characteristics in terms of strength, density and hardness .Different fiber orientations of a composites shaft strIn the present work an effort has been made to design an E-Glass /Epoxy and HM Carbon/Epoxy composite drive shafts to withstand torque loads and layer stacking sequence of lamina for torque loads. A one-piece 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 mass of metal shaft, it was investigated with respect to the steel shaft. The drive shaft can be solid circular or hollow circular. Here hollow circular cross-section was chosen because the

Fig.1: One piece composite drive shaft.

Hollow circular shafts are stronger in per kg weight than solid circular and the stress distribution in case of solid shaft is zero at the center and maximum at the outer surface while in hollow shaft stress variation is smaller. The following Material Properties are taken for the simulation.

Table.1.Composite Material Properties

Properties	E-glass/ Epoxy	HM carbon/Epoxy
Young's modulus e11	50GPa	190GPa
Young's modulus e22	12GPa	7.7GPa
Density	2000Kg/ m^3	1600Kg/ m^3
Poisson ratio	0.3	0.3
Shear modulus(g)	5.6GPa	4.2GPa

Composite materials

Composite materials are those containing more than one bonded material, each with different material properties. The major advantages of composite materials are that they have a high ratio of stiffness to weight and strength to weight. A principal advantage of composite materials lies in the ability of the designer to tailor the material properties to the applications

Classification of Composite Materials

Based upon the reinforcements, the composite materials are classified as fiber reinforced composite, filled composite, flake composite, particulate composites and laminates. The fiber composites can be further classified as whisker composites and continuous fiber composites. Based upon the matrix, composite materials are classified as metal matrix composites, polymer matrix composites and ceramic matrix composites.

II.METHODOLOGY

Theoretical calculations the following dimensions of Ecomet 1611 model vehicle drive shaft dimensions are chosen. Modal Analysis using ANSYS is performed with different conditions.

Torque	=	400Nm
Length of shaft	=	1.47m
Outer diameter	=	0.09m
Inner diameter	=	0.085m
Moment inertia	=	$6.5\times10^{-7}m^4$
Area	=	$6.8\times10^{-4}m^2$
Thickness	=	0.005m
Speed	=	1500rpm

Form Composite material Calculations 8 no of different layers are chosen and for the composite shaft manufacturing are mentioned in the sequential order the following Lamina Sequences are chosen, the ply angles are chosen.

Lamina Sequence
[-750/750/150/650/-650/850/-150/-850]

Lamina Sequence
[$85^0/75^0/-65^0/65^0$ 2 $/75^0/-75^0/-65^0$]

Lamina Sequence
[-650/150/650/-650/850/150/-850/750]

Lamina Sequence
[150/850/-850 /150 /650/750/-650/650]

Using Bernoulli-Euler Beam theory:
This Theory will not consider both Transverse shear deformation as well as rotary inertia effects

$F_b = \pi P^2/2L^2 \times \sqrt{(EI/\rho A)}$,

Here P = 1, 2, 3…

Using Timoshenko beam theory:
This Theory consider both Transverse shear deformation as well as rotary inertia effects, for solving modal analysis we will consider this theory

$F_t = k_s \times 30\, \pi P^2/L^2 \times \sqrt{(E r_m^2/2\rho)}$

$1/ks2 = 1 + (n^2\pi^2 r_m^2/2L^2 \times (1 + [f_s E/G])$

Using the relation between Timoshenko and Bernoulli-Euler beam frequency of composite material can be determined.

$F_b \times k_s = F_t$

By using the following relations natural frequencies are calculate, similarly for steel material also the natural frequencies are calculated.

III.RESULTS

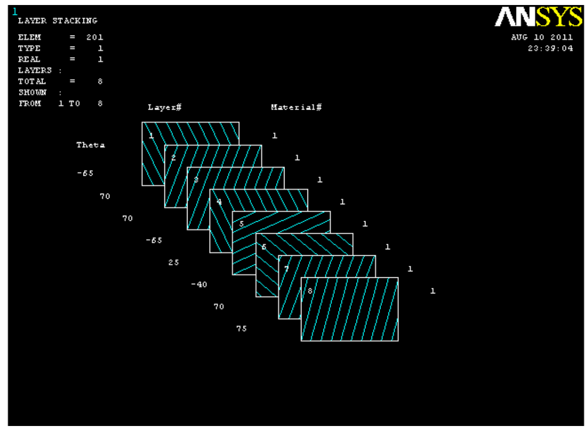


Fig.2.[$-65^0/70^0/70^0/-65^0/25^0/-40^0/70^0/75^0$]

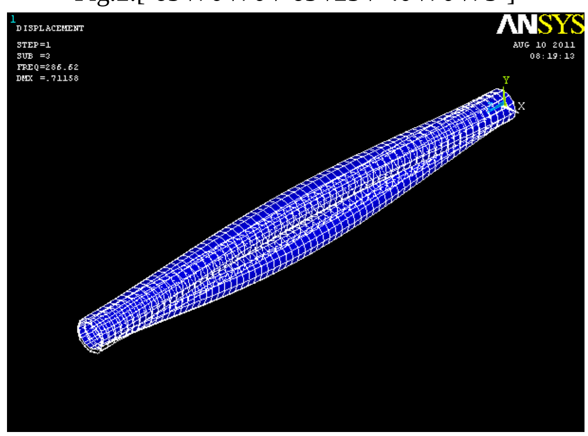


Fig.3.Mode 1

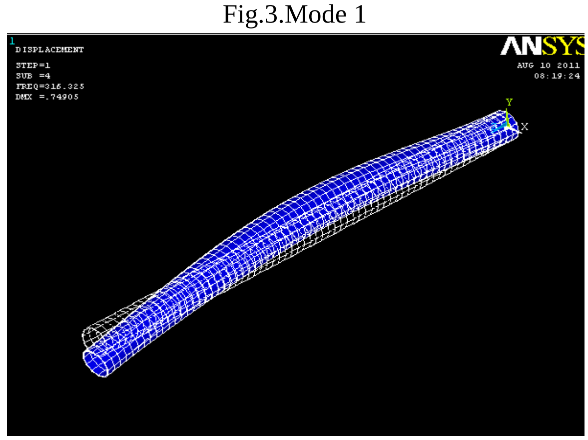


Fig.4.Mode 2

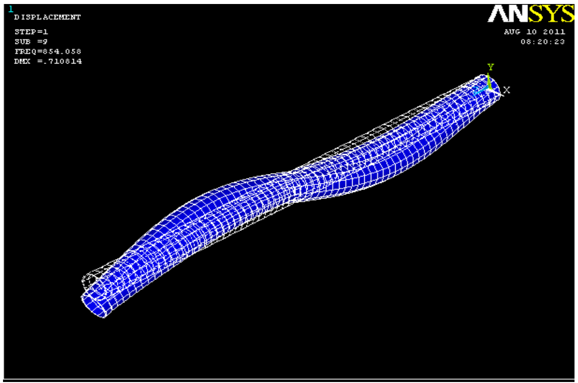


Fig.5.Mode

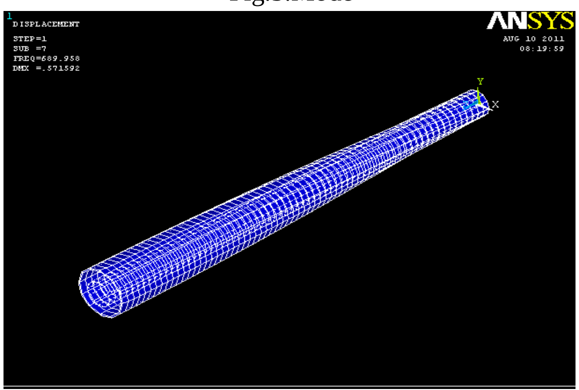
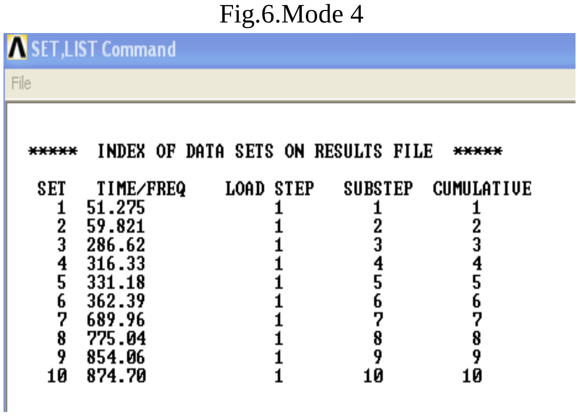


Fig.6.Mode 4



SET,LIST Command

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2	59.821	1	2	2
3	286.62	1	3	3
4	316.33	1	4	4
5	331.18	1	5	5
6	362.39	1	6	6
7	689.96	1	7	7
8	775.04	1	8	8
9	854.06	1	9	9
10	874.70	1	10	10

Fig.7.frequency Values

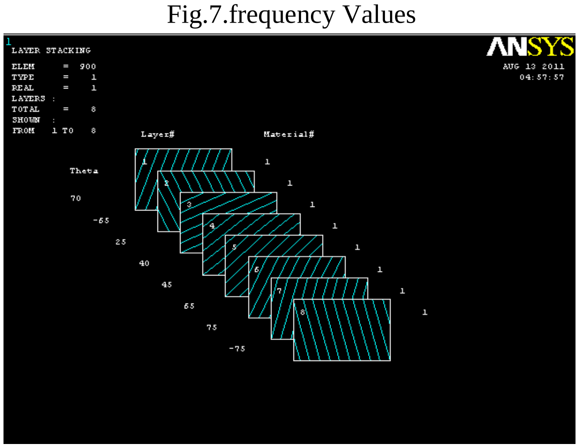
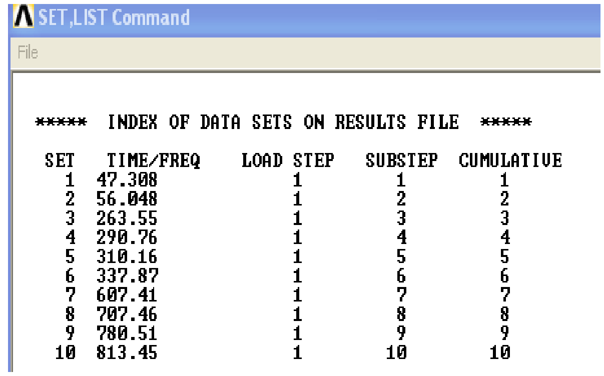


Fig.8.[70^0/-65^0/25^0/40^0/45^0/65^0/75^0/-75^0]



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4	290.76	1	4	4
5	310.16	1	5	5
6	337.87	1	6	6
7	607.41	1	7	7
8	707.46	1	8	8
9	780.51	1	9	9
10	813.45	1	10	10

Fig.9.Frequency values

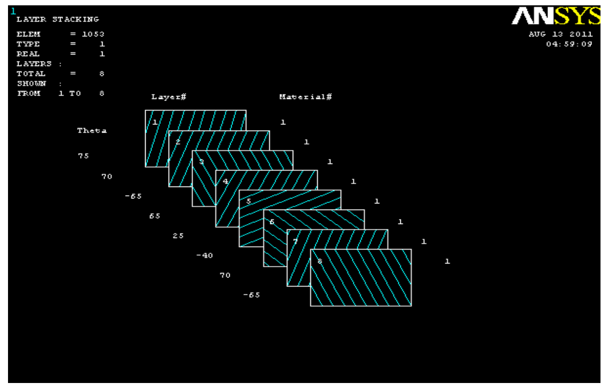
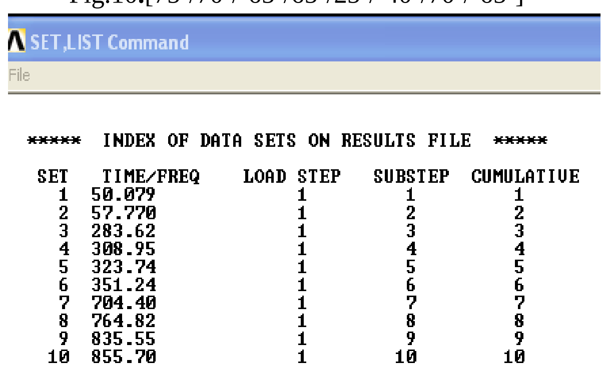


Fig.10.[75^0/70^0/-65^0/65^0/25^0/-40^0/70^0/-65^0]



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1	50.079	1	1	1
2	57.770	1	2	2
3	283.62	1	3	3
4	308.95	1	4	4
5	323.74	1	5	5
6	351.24	1	6	6
7	704.40	1	7	7
8	764.82	1	8	8
9	835.55	1	9	9
10	855.70	1	10	10

Fig.11.Frequency values

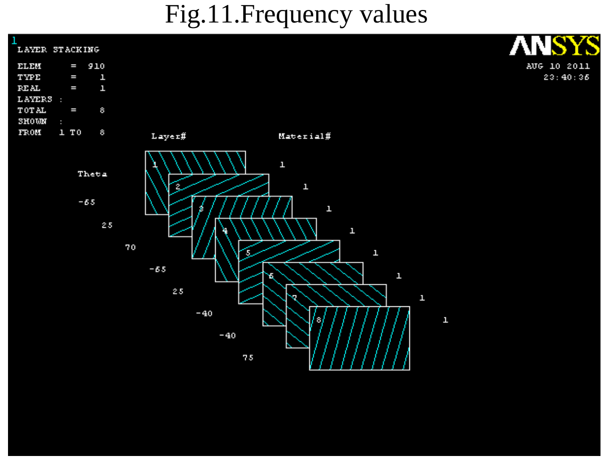
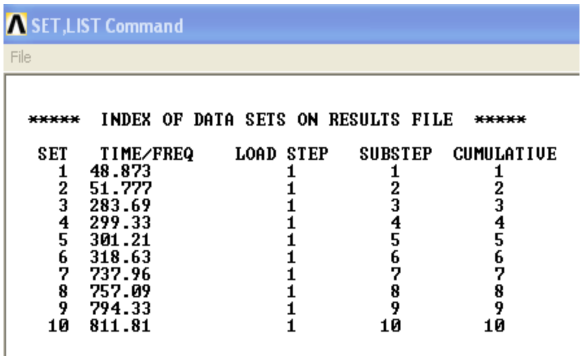


Fig.12.[-65^0/25^0/70^0/-65^0/25^0/-40^0/-40^0/75]



SET,LIST Command

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2	51.777	1	2	2
3	283.69	1	3	3
4	299.33	1	4	4
5	301.21	1	5	5
6	318.63	1	6	6
7	737.96	1	7	7
8	757.09	1	8	8
9	794.33	1	9	9
10	811.81	1	10	10

Fig.13.Frequency values

E-GLASS/EPOXY SHAFT

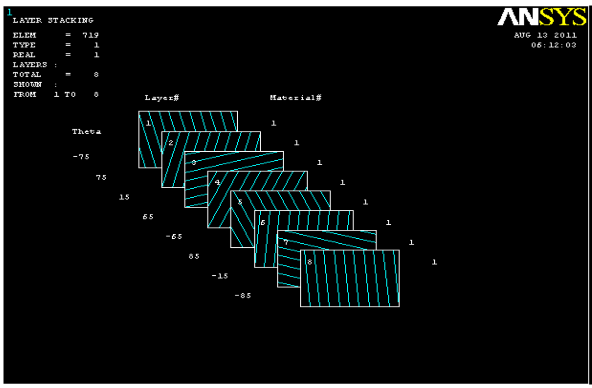


Fig.14 .E-glass/epoxy: [-75^0/75^0/15^0/65^0/-65^0/85^0/-15^0/-85^0]

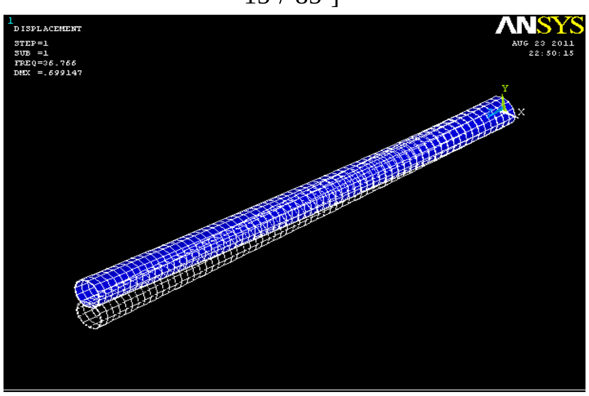


Fig.15.Mode 1

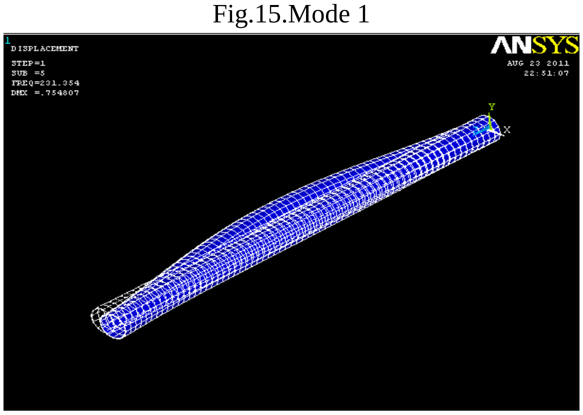


Fig.16.Mode 2

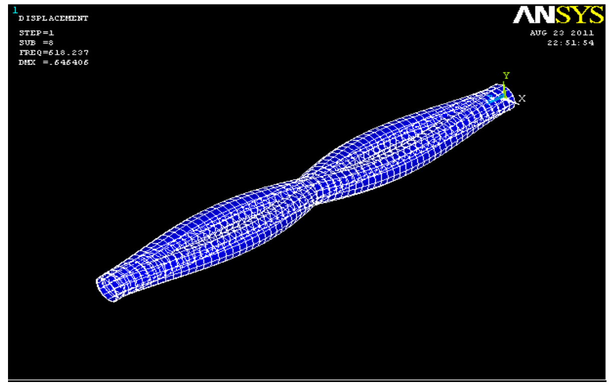
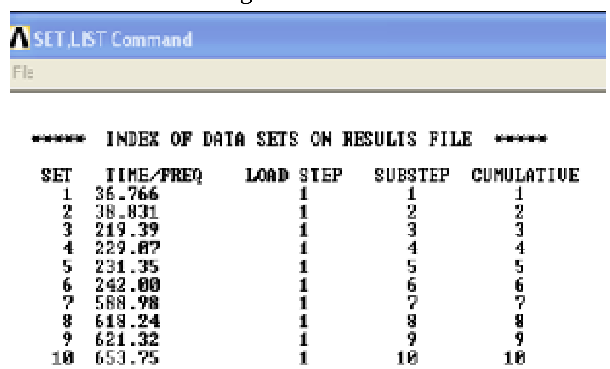


Fig.17.Mode 3



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2	38.031	1	2	2
3	219.39	1	3	3
4	229.07	1	4	4
5	231.35	1	5	5
6	242.00	1	6	6
7	588.98	1	7	7
8	618.24	1	8	8
9	621.32	1	9	9
10	653.75	1	10	10

Fig.18.Frequency values

IV.CONCLUSION

The modal analysis results shows that the critical speed of the shaft is near to the running speed (1500 rpm) of the machine when the shaft is made up of E-glass epoxy and may result in possible resonance phenomenon compared to shafts made of other materials (steel 2460, HM carbon epoxy is 3076 rpm) so with respect to critical speed HM carbon epoxy is the best material. The present work aimed at finding the composites which will have reduced weight without affecting the performance of the shaft. The chosen ply sequence is at random. This may not be the best solution possible to find the best possible ply sequence and no. of plies, a maximizing function have to be developed and optimization techniques have to be applied (like Genetic Algorithms, Expert systems, simulated annealing)

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