NONLINEAR STATIC ANALYSIS OF COMPOSITE DRIVE SHAFT OF MEDIUM UTILITY VEHICLE TO EVALUATE EFFECT OF NONLINEAR PARAMETERS

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ABSTRACT

In this paper numerical static analysis of composite drive shaft is carried out to find out effect of nonlinearities. For Linear and Nonlinear Finite Element Analysis ANSYS software is used. Experimental set up is developed in order to find out Torque-Angular Displacement characteristics of Composite drive shaft.Torque-Angular Displacement characteristics are studied in order to find out torsional stiffness of drive shaft and to evaluate nonlinearities present in composite drive shaft. The present work deals with the numerical analysis of composite drive shaft with nonlinear parameters. In this paper Material and Geometric nonlinearities are considered.

***Keywords*: ANSYS, Composite Drive Shaft, E-Glass/Epoxy, Nonlinearity.**

I INTRODUCTION

Drive shafts as power transmission tubing are used in many applications, including cooling towers, pumping sets, aerospace, trucks and automobiles. In metallic shaft design, knowing the torque and the allowable shear stress for the material, the size of the shaft's cross section can be determined. Polymer matrix composites such as carbon/epoxy or glass/epoxy offer better fatigue characteristics because micro cracks in the resin do not freely propagate as in metals, but terminate at the fibers. Generally, composites are less susceptible to the effects of stress concentration, such as are caused by notches and holes, compared with metals [1]. An efficient design of composite drive shaft could be achieved by selecting the proper variables, which are specified to minimize the chance of failure and to meet the performance requirements. In the optimal design of the drive shaft, these variables are constrained by the lateral natural frequency, torsional vibration, torsional strength and torsional buckling of the shaft [2].

Composite materials consist of two or more physically dissimilar and instinctively separable components called reinforcement and matrix. These two components can be mixed in a restricted way to achieve optimum properties, which are superior to the properties of each individual component. Composite materials have been widely used in automobile industry because of its high strength and modulus to weight ratio, low cost and flexibility in material and structure design.

CAE tools are widely used in the automotive industries. In fact, their use has enabled the automakers to reduce product development cost and time while improving the safety, comfort, and durability of the vehicles they produce. The predictive capability of CAE tools has progressed to the point where much of the design verification is now done using computer simulation rather than physical prototype testing. CAE dependability is based upon all proper assumptions as inputs and must identify critical inputs. Even though there have been many advances in CAE and it is widely used in the engineering field, physical testing is still used as a final confirmation for subsystems due to the fact that CAE cannot predict all variables in complex assemblies, therefore the validation of CAE results is important [2].

In this analysis the material of composite drive shaft is Aluminum-E- Glass Epoxy. There are four layers of material lay up by following way:

The E Glass Epoxy is also type of fiber,SiO_2 54wt%, Al_2O_3 14wt%,CaO+MgO 22wt%, $B_2O_3$10wt%, Na_2O+K_2O less than 2wt%. The properties of E-Glass Epoxy material used for the analysis are as follows:

II MATERIAL PROPERTIES E-GLASS EPOXY

Sr. No.	Property	Value
1	Tensile Modulus Along X-Direction	34000MPa
2	Tensile Modulus Along Y-Direction	6530MPa
3	Tensile Modulus Along Z-Direction	6530MPa
4	Tensile Strength of Material	900MPa
5	Compressive Strength of Material	450MPa
6	Shear Modulus Along XY-Direction	2433MPa
7	Shear Modulus Along YZ-Direction	1698MPa
8	Shear Modulus Along ZX-Direction	2433MPa
9	Poisson Ratio Along XY-Direction	0.217
10	Poisson Ratio Along YZ-Direction	0.0366
11	Poisson Ratio Along ZX-Direction	0.217
12	Mass Density	$2.6*10^3 Kg/mm^3$
13	Flexural Modulus	40000MPa
14	Flexural Strength	1200MPa

III NUMERICAL ANALYSIS

The Finite Element Method (FEM) is practical application often known as Finite Element Analysis (FEA) is a numerical technique for finding approximate solutions of partial differential equations (PDE) as well as of integral equations. Finite Element Analysis is a simulation technique which evaluates the behavior of components, equipment and structures for various loading conditions including applied forces, pressures and temperatures. Thus, a complex engineering problem with non-standard shape and geometry can be solved using finite element analysis where a closed form solution is not available. The finite element analysis methods result in the stress distribution, displacements and reaction loads at supports etc. for the model. The three dimensional model of spring is drawn in CATIA V5 R16 environment. This geometry is imported to ANSYS environment. 20 node hexahedral element SOLID-95 used for meshing of the geometry. Meshing is done by Hexagonal Sweep. The geometry can be meshed by 10 node tetrahedron element as well but tetrahedron is stiffer as compared to hexahedron element so results in lower accuracy [4].In this paper linear and nonlinear analysis of composite drive shaft is carried out using ANSYS.

In finite element analysis 3D model of composite drive shaft is developed. After modeling of composite drive shaft the actual supporting boundary conditions are given. i.e. fixed support at one end and torque at other end. In fixed support there is no any degree of freedom i.e. there is no displacement at any direction. Torque is applied on mass 21 element which has negligible mass and which is applied on flange by use of constrained equations.

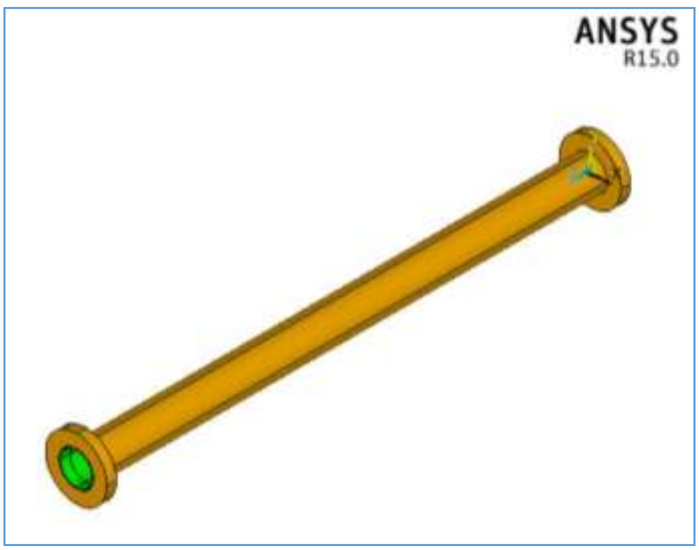


Fig..1 Cad Model of Composite Drive Shaft

In ANSYS the Cad Model of composite drive shaft is imported. After that for analysis the Finite element model is generated. At the point of application of load the fine meshing is done. After meshing we get total 56667 No. of Nodes and 39385 No. of Elements.

Fig..2 Shows meshed model of composite drive shaft spring. Fig..3 shows angular displacement of linear composite Drive Shaft at 2400 Nm.

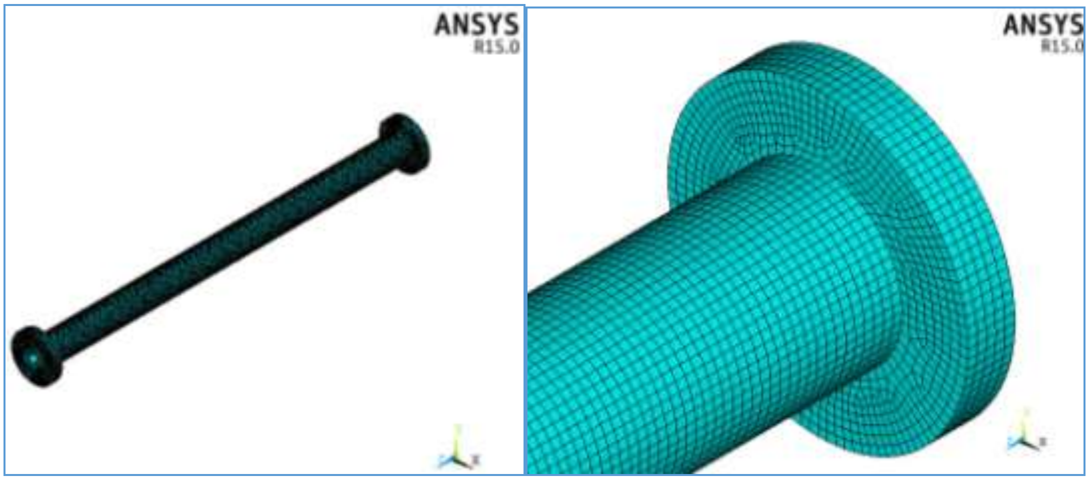


Fig.2 Meshed Model of Composite Drive Shaft

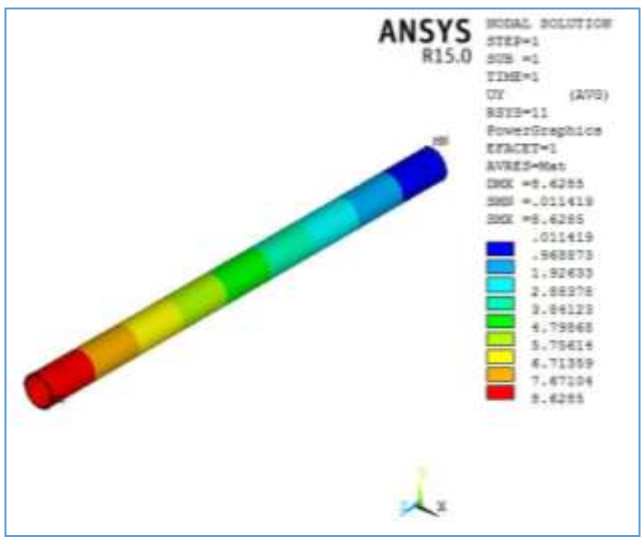


Fig.3 Angular Deformation of Linear Composite Drive Shaft at 2400 Nm .

3.1 Nonlinear Finite Element Analysis

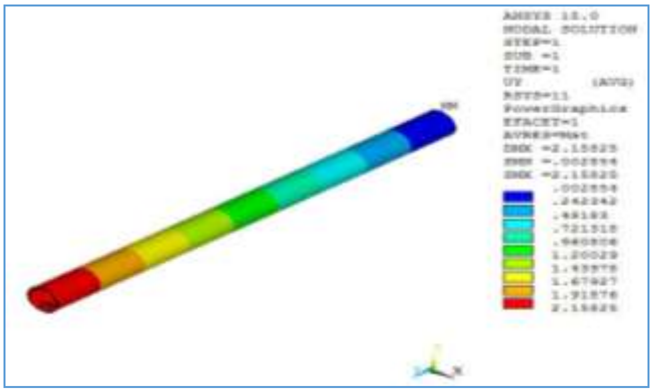
i) Material Non-Linearity: Force (stress) Vs. Displacement (strain) curve is Nonlinear(polynomial).

ii) Geometric Non-Linearity: In real life, the stiffness [K] is a function of Displacement [d]. This means in a geometric nonlinear analysis, the stiffness [K] is re-calculated after a certain predefined displacement.

iii) Contact Non-Linearity: In contact analysis, the Stiffness [K] also changes as a function of Displacement (when parts get into contact or separate). Non-linear analysis deals with true stress and strain (unlike engineering stress and strain in linear static analysis) [5].

In this paper Material and Geometric nonlinearities are considered to find out Torque Vs. Angular Deflection characteristics and maximum equivalent stress contours (Von Misses Stress plots).

For maximum load acting on composite drive shaft 66.27 MPa equivalent stress is developed which is far below yield strength of material, hence design of composite drive shaft is also safe. Fig..4a. shows angular Deflection of nonlinearcomposite drive shaft at 2400 Nm and Fig.4b and 4c shows maximum equivalent stress in nonlinear composite drive shaft.



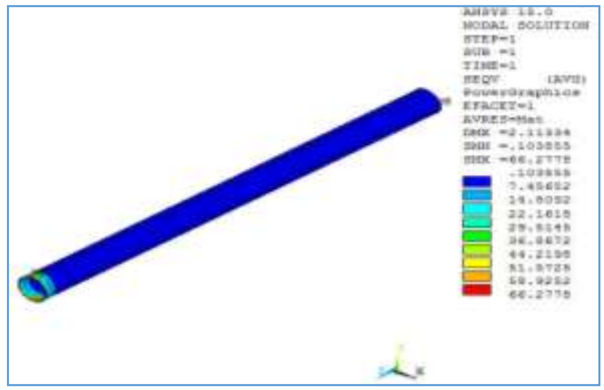


Fig.4a **Fig.4b**

Fig.4a Angular Deflection of Linear Composite Drive Shaft at 2400 Nm.

Fig.4b Maximum Equivalent Stress in Non-Linear Composite Drive Shaft.

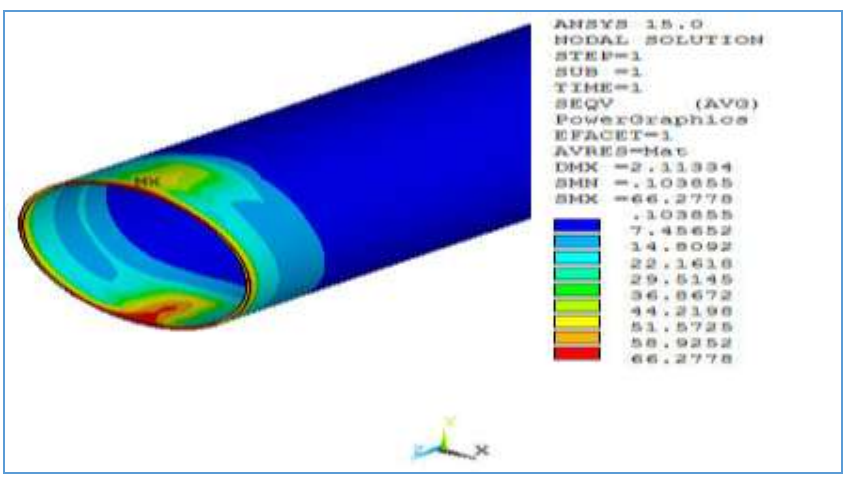


Fig.4c Maximum Equivalent Stress in Non-Linear Composite Drive Shaft.

IV EXPERIMENTAL RESULTS

The experimentation is done by using Torsion Testing Machine. The torque is applied by using the torsion testing machine. At various torque the deflection of composite drive shaft is measured. The following results are obtained during the experimental analysis of composite drive shaft. Experimental results show good agreement with load-deflection characteristics of nonlinear composite drive shaft.

Fig.4 Experimental Setup

V RESULTS AND DISCUSSIONS

Table 1 shows the comparative Torque-Angular deflection characteristics of numerical linear and nonlinear composite drive shaft and experimental analysis.

Table. 1: Torque-Angular Deflection Characteristics

Sr.No.	Torque (Nm)	Angular Deflection of Linear Composite Drive Shaft (rad)	Numerical Angular Deflection of Nonlinear Composite Drive Shaft (rad)	Experimental Angular Deflection of Composite Drive Shaft (rad)
1	300	1.373265243	0.988777459	1
2	600	2.746530487	1.473762041	1.5
3	900	4.119808463	1.800335251	1.6
4	1200	5.493073706	2.053264287	1.98
5	1500	6.866338949	2.262903178	2
6	1800	8.239604193	2.443690461	2.4
7	2100	9.612869436	2.603711207	2.5
8	2400	10.98614741	2.747969247	2.6

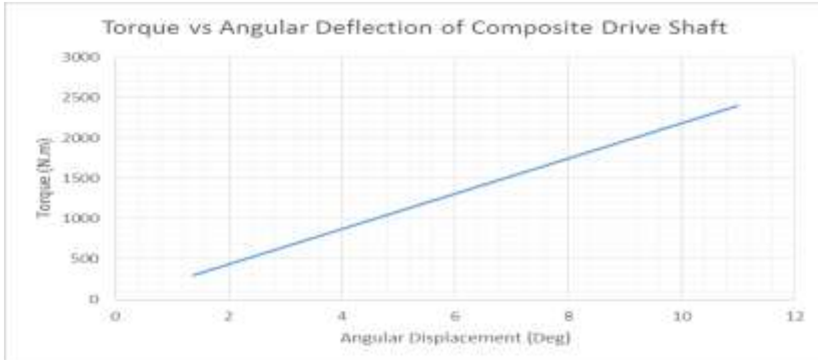


Fig.5a-Torque-Angular Deflection characteristics of Numerical Linear Composite Drive Shaft.

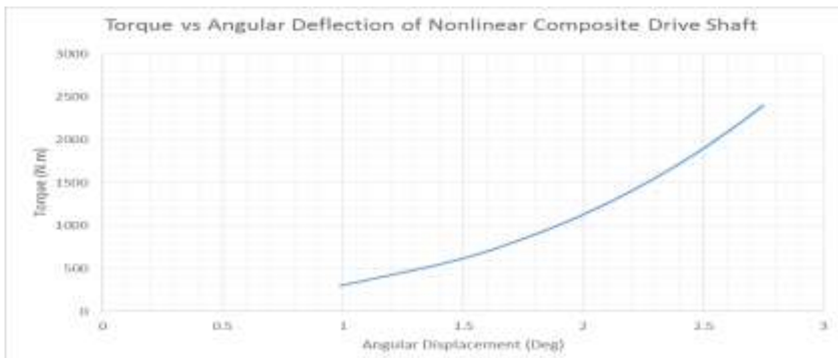


Fig.5b-Torque-Angular Deflection characteristics of Nonlinear Composite Drive Shaft

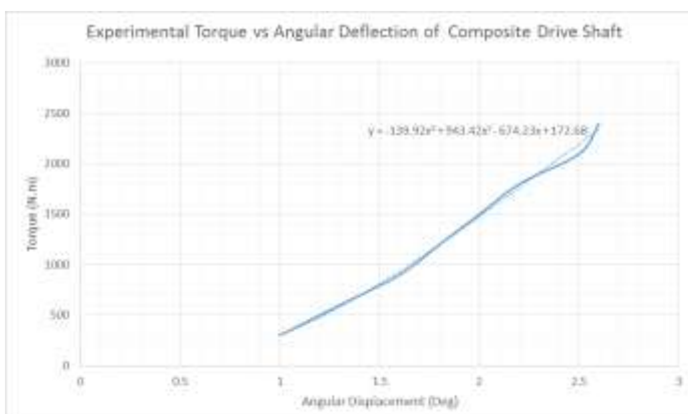


Fig.5c-Experimental Torque-Angular Deflection characteristics of Composite Drive Shaft

From experimental Torque-Angular Deflection characteristics it is observed there is good agreement between Torque-Angular Deflection characteristicsof Nonlinear Composite Drive Shaft and experimental Torque-Angular

Deflection results, therefore in order to find out non-linear effects included in the torsional Stiffness' t_s', it is modeled as third order polynomial function as

$$Ts = k_0 + k_1\Delta x + k_2\Delta x^2 + k_3\Delta x^3$$

Where the co-efficients are obtained by fitting the experimental data, which resulted in k_3 = -139.92 N/m^3, k_2 =-943.42 N/m^2, k_1= -674.23 N/m and k_0 = 172.68 N. Hence, in order to model the nonlinearities in composite drive shaft above equationwill be used, which includes the nonlinear effects in stiffness,

VI CONCLUSION

Comparative Nonlinear Static Analysis of Composite Drive Shaft used in medium utility vehicle is carried out. Nonlinearities present in drive shaft are found out. The theoretical results from Nonlinear Finite Element Analysis showed in general a good agreement with the experimental values. However, differences appear indicating the necessity to improve the model input data and the experimental procedure. By using nonlinear analysis simulation of real life conditions which were not possible in linear analysis is possible, hence it is essential to carry out nonlinear analysis to get real life results.

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