Finite Element Analysis and Modal Analysis of Shaft Composite Materials

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Abstractts.*Composite materials are normally used in structures thatclaim a high level of mechanical recital. Their highstrength to weight and stiffness to weight ratios has facilitatedthe development of lighter structures, which often replaceconventional metal structures. Passivedamping is used to suppress vibrations by reducingpeak resonant response. Viscoelastic dampingmaterials add passive damping to structures bydissipating vibration strain energy in the form of heatenergy. The incorporation of damping materials inadvanced composite materials offers the possibility ofhighly damped, light-weight structural componentsthat are vibration-resistant. The aim of the project isto analyze the shaft without damping material andwith damping material. The present used material forshaft is steel. In this thesis, the composite materialsconsidered are HM Carbon Epoxy and HS CarbonEpoxy. The material for damping is rubber. Thestructural analysis is done to verify the strength ofthe shaft and compare the results for three materials.Modal analysis is done on the shaft to determinemode shapes.*

Keywords-Modelling, Analysis, Ansys, Composite shafts, Automative applications, etc.

I. INTRODUCTION

Composite materials are commonly used in structures thatdemand a high level of mechanical performance. Their highstrength to weight and stiffness to weight ratios has facilitatedthe development of lighter structures, which often replaceconventional metal structures. Rapid technological advancesin engineering design field result in finding the alternatesolution for the conventional materials. The design engineersbrought to a point to finding the materials which are morereliable than conventional materials. Researchers anddesigners are constantly looking for the solutions to providestronger and durable materials which will answer the needs offellow engineers. Drive shafts are used as power transmissiontubing in many applications, including cooling towers,pumping sets, aerospace, trucks and automobiles. In thedesign of metallic shaft, knowing the torque and the allowableshear stress for the material, the size of the shaft's crosssection can be determined. In the today's days there is a heavyrequirement for lightweight materials vehicle. Theconventional steel material is replaceable by advancedcomposite materials. Composite materials are favored by mostof the scientist in the design of automobiles due to its higherspecific strength and stiffness. Weeton et al. [1] stated thepossibilities of replacing the conventional steel material bycomposites in the field of automobile. Weeton et al describethe possibilities of composites used to replace the steel leafspring as well as steel drive shaft. The advanced compositematerials such as graphite, carbon, Kevlar and glass withsuitable resins are widely used because of their high specificstrength (strength / density) and high specific modulus(modulus / density). The first application of composite driveshaft to automotive was the one developed by Spicer U-jointdivisions of Dana Corporation for the Ford econoline vanmodels in 1985. Drive shafts for power transmission are usedin many applications, including cooling towers, pumping sets,aerospace, structures, and automobiles.

II. RELATED WORKS

M.A. Badie et al. [1] examines the effect of fiberorientation angles and stacking sequence on thetorsional stiffness,natural frequency, buckling strength,fatigue life and failure modes of composite tubes.Finite element analysis (FEA) has been used to predictthe fatigue life of composite drive shaft (CDS) usinglinear dynamic analysis for different stackingsequence. Experimental program on scaled wovenfabric composite models was carried out to investigatethe torsional stiffness. FEA results showed that thenatural frequency increases with decreasing fiberorientation angles.

Mahmood M. Shokrieh et al. [2] has done Shearbuckling of composite drive shaft under torsion wasperformed using FEM. The commercial finite elementpackage ANSYS was used for the solution of theproblem. In order to achieve model the compositeshaft, the shell 99 element is used and the shaft issubjected to torsion. The shaft is fixed at one end inaxial, radial and tangential directions and is subjectedto torsion at the other end. After performing a staticanalysis of the shaft, the stresses are saved in a file tocalculate the buckling load. The output of the bucklinganalysis is a load coefficient which is the ratio of thebuckling load to the static load.

S.A. Mutasher [3] investigates the maximum torsioncapacity of the composite shaft for different windingangle, number of layers and stacking sequences. TheComposite shaft consists of aluminum tube woundoutside by E-glass and carbon fibers/epoxy composite.The finite element method has been used to analyze thehybrid shaft under static torsion. ANSYS finiteelement software was used to perform the numericalanalysis for the shaft. The specimen was analyzed.Elasto-plastic properties were used for aluminum tubeand linear elastic for composite materials. The resultsshow that the static torque capacity is significantlyaffected by changing the winding angle, stackingsequences and number of layers.

Y.A. Khalid et al [4] studied a bendingfatigue analysis was carried out for composite driveshafts. The shafts used were fabricated using filamentwinding technique. Glass fiber with a matrix of epoxyresin and hardener were used to construct the externalcomposite layers needed. Four cases were studiedusing aluminum tube wounded by different layers ofcomposite materials and different stacking sequence orfiber orientation angles. The failure mode for all thehybrid shafts was identified

III. METHODOLOGY AND MATERIALS USED

The study is concern with the replacement and design of conventional two piece drive shaft with single piece composite material drive shaft for medium duty vehicle. Composite materials haveadvantageof higher specific strength, less weight, high damping capacity, longer life, high critical speed and greater torque carrying capacity. The main function of drive shaft is to transmit torque from transmission to the rear wheel differential system. Heavy vehicle medium duty truck transmission drive shaft has been selected as research object. The conventional material steel SM45C, stainless steel and composite materials HS carbon epoxy, E-glass polyester, Kevlar epoxy have been used for drive shaft study. The drive shaft design and performance was enhanced by reducing the weight. For strength and rigidity purpose structural and free vibration analysis were performed. Pro-E software has good modelling features. Drive shaft was designed using Pro-E. Finite Element Analysis (FEA) based ANSYS 14.5 has been used as an analysis tool for numerical simulation to find the dynamic vibration response of composite material drive shaft. The simulation result shows that the natural frequency of free vibration varies from 0 Hz to 919 Hz. The simulation result determines the deflection, strain, principal stress, strain energy, natural frequencies and mode shapes under actual boundary conditions. The result concluded that HS carbon epoxy composite material suited more for composite drive shaft application. A propeller shaft, transmission drive shaft, driving shaft, drive shaft or cardan shaft is an automobile mechanical component. Conventionally it is manufactured using Steel material in two-piece and used for transmitting torque and rotation, at the same time it is also used to connect mechanical components of drive train that are not directly connected from transmission or engine to rear end of vehicle. This type of transmission drive shaft is known as propeller shaft. Two-piece drive shaft consists of two or more universal joints with jaw coupling which increases the total weight of drive shaft and decreases the performance. Truck transmission longitudinal drive shaft is subjected to shear stress, torsion, lateral vibration and torsional vibration. The strength and weight are two technical indexes for drive shaft failure. Authors have studied single piece drive shaft using composite materials. Various previous research work was studied for reference work.

Composite materials have higher specific stiffness to provide the required strength against less weight. Higher stiffness of composite material solves the problem of high strength requirement for drive shaft and less weight solves the problem of inertia. So composite material can be used as one-piece drive shaft material without resonance. In this work HS carbon epoxy and E-glass polyester has been used as a composite material for single-piece drive shaft analysis. The one-piece drive shaft of truck was specified for the study and the modelling of the drive shaft assembly was done using Pro-E. The weight of drive shaft was optimised to reduce the inertia and torsional vibration problem.

CAD Model of Single-Piece Drive Shaft: Single-piece drive shaft was designed using the Solid Edge and Pro-E software. FEA based analysis was done using Ansys 14.5. The result of this study provides the reference work for the structure optimisation and performance evaluation of single-piece drive shaft aims at reducing vibration and strength problem. Free vibration study of heavy vehicle, single-piece composite material drive shaft was performed to evaluate the inherent natural frequency and vibration mode shape to prevent the resonance. For structure rigidity the natural bending frequency should be high. The structure analysis has evaluated the strength properties of drive shaft. The design model of automobile truck drive shaft consists of a single-piece shaft with universal joints at ends portion. Figure.1 shows the single-piece drive shaft with universal joint. ANSYS 14.5 program solver works on meshing concept of nodes and elements (nodes- 87718, elements-453477.

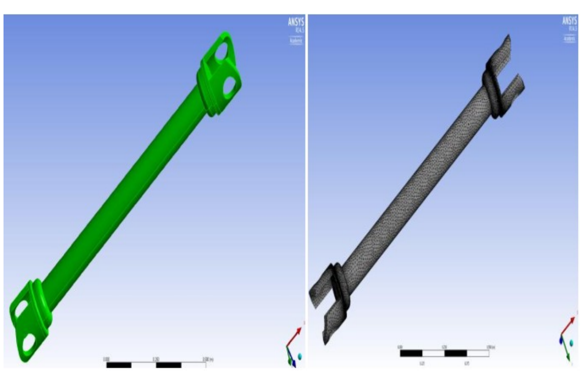

Figure.1 CAD and FEA mesh model of transmission drive shaft.

Numerical simulation method is used for structural and free vibration analysis. In study of drive shaft it was assumed that the shaft is balanced, has circular cross section and rotates at constant speed. The nonlinear and damping effects were neglected. The advantage of composite materials has attracted the scientist worldwide. It has many applications in automobile fields. It has advantage of high specific strength and less weight, high torque carrying capacity, corrosion resistance, high damping. The advantage of composite material leads less fuel consumption and less noise, vibration. The fatigue life of composite material is high. Composite materials HS-Carbon Epoxy, E Glass Polyester Resin and Kevlar Epoxy were used for single-piece drive shaft study.
The 2D model of shaft reinforcement is made inPROE. After that is imported into wokbench foranalysis. Stress and deformation is observed. We areapplied force on shaft for calculating deformations.Now by using Newton's second law, we calculatedforce value according to respected speeds forrespective materials. This point force applied centrallyon Shaft.

Material selection: Three types of material are selected for shaft mainlyfollowing specification:

Table.1 Materials used

	Steel SM 45C	HS carbon Fiber	HM carbon Fiber
Density(Kg/m^3)	7600	1600	1650
Young's Modulus(MPa)	20700	134000	195000
Poissions ratio	0.3	0.3	0.3
Strength(MPa)	335	5000	4900

Modelling of shaft

Different modules in pro/engineer
- Part design
- Assembly
- Drawing
- Sheetmetal
- Manufacturing

IV. RESULTANALYSIS

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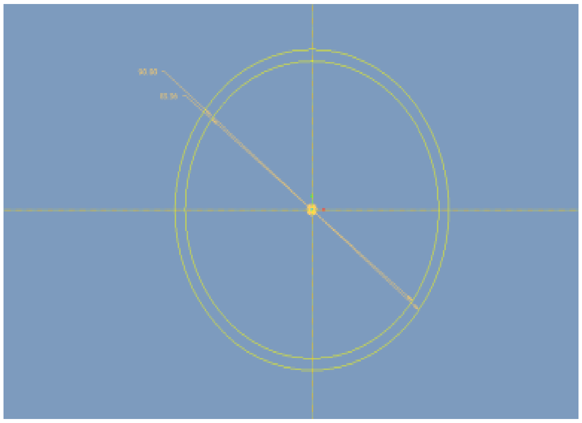
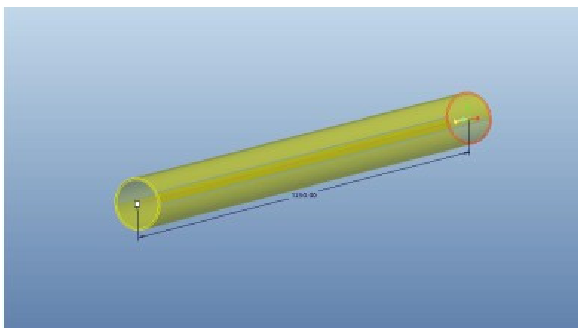
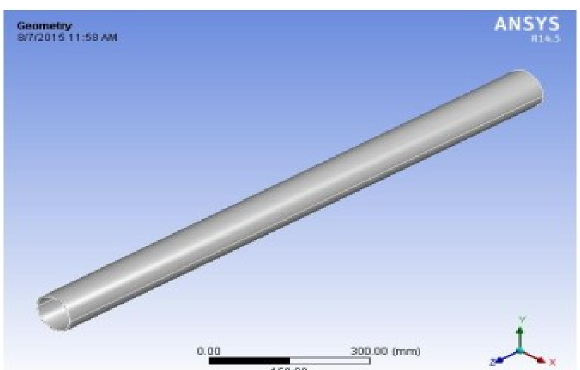
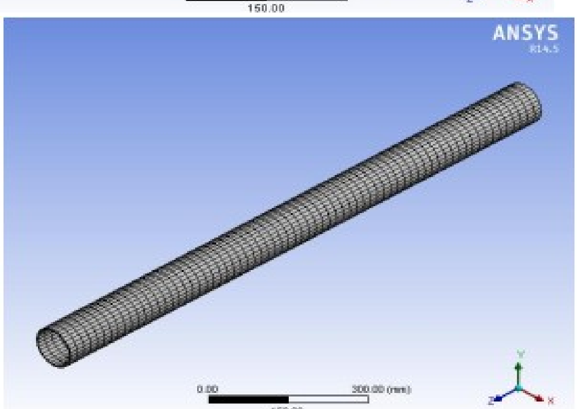
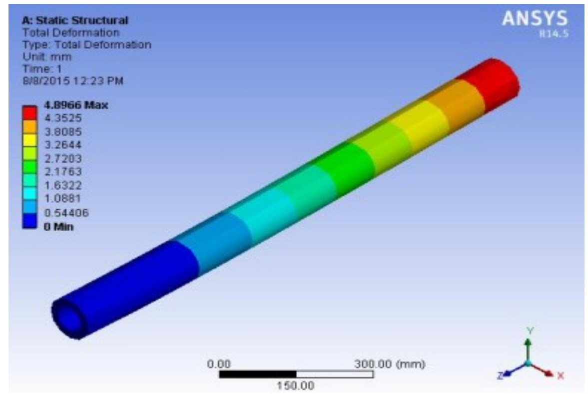




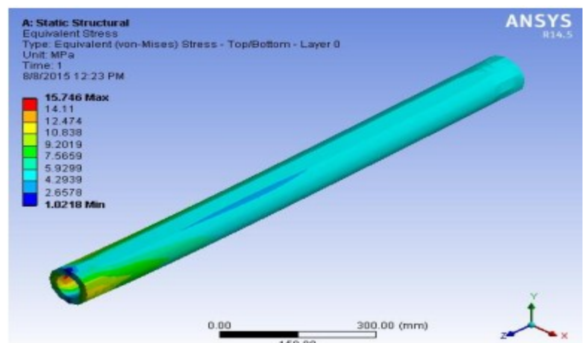




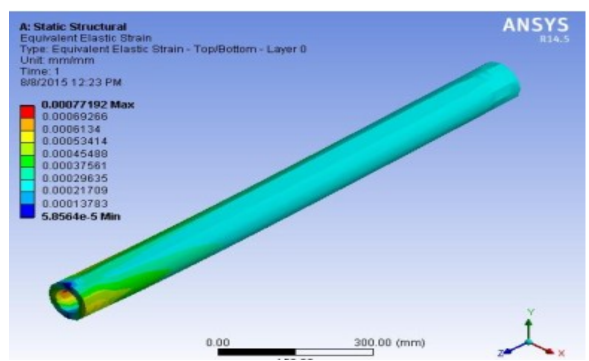
With damping material (rubber)Material – Steel (SM 45C)



Total Deformation



Von-MisesStress



VON-MISES Strain

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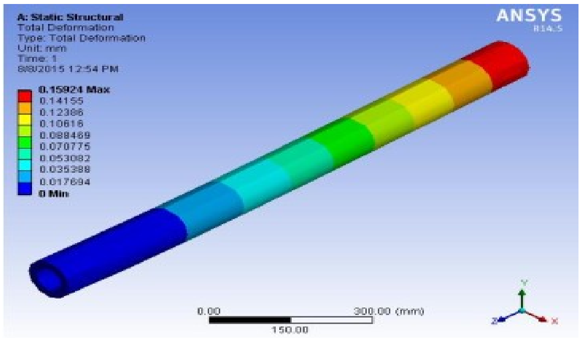
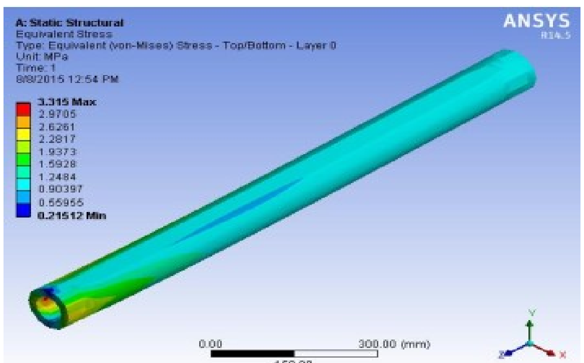


Material HS-Carbon/EpoxyTotal deformation



VON-MISES Stress

V. CONCLUSION

In this paper, the shaft is analyzed without dampingfabric and with damping fabric. As this time used the material for the shaft is metal. In this paper, the compositematerials regarded are HM Carbon Epoxy and HSCarbon Epoxy. The composite materials areconsidered due to their excessive strength to weight ratio.The material for damping is rubber.The structural analysis is done to verify the force ofthe shaft and examine the outcome for 3 substances.Through observing the evaluation outcome, the stress values areless when composite fabric Carbon Epoxy is usedwhen compared with that of steel.Structural analysis can be done on the shaft using shellaspect without damping fabric and with dampingmaterial rubber. The stresses are extra when dampingfabric is used than without damping material however thestresses are within the range. By using making use of dampingmaterial force increases within the shaft therebyreducing vibrations.

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