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DESIGN AND ANALYSIS OF COMPOSITE DRIVE SHAFT

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ABSTRACT

This paper is design and analysis of composite drive shaft. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. This work deals with the replacement of conventional steel drive shafts with a composite drive shaft. The design parameters were optimized with the objective of minimizing the weight of composite drive shaft. Advanced composite materials can be defined as combination of materials appropriately arranged using reinforcing fibers, carefully chosen matrixes, and sometimes auxiliary materials like adhesive core and other inserts. These combinations after proper manipulation and processing result in finished structure/item with synergistic properties i.e. properties achieved after fabrication cannot be obtained by individual components acting alone. FEM methods play a significant role in analyzing of Composite materials. Present work is conducted to analyze the composite drive shaft by the FEM software ANSYS 14.5.Results and graphs will be recorded and presented in the documentation.

I. INTRODUCTION

Nowadays, composite materials are used in large volume in various engineering structures including spacecrafts, airplanes, automobiles, boats, sports' equipments, bridges and buildings. The widespread use of composite materials in industry is due to the excellent characteristics such as, specific strength and specific hardness or strength-weight ratio and hardness-weight ratio. The application of composite materials started first at the aerospace industry in 1970s, but nowadays after only three decades, it has been developed in most industries. Meanwhile, the automotive industry, considered as a pioneer in every country, has been benefited from the properties and characteristics of these advanced materials. Along with progress in technology, metallic automotive parts have been replaced by composite ones. Power transmission drive shafts are used in many applications, including cooling towers, pumping sets, aerospace, structures, and automobiles. Drive shafts are usually made of solid or hollow tube of steel or aluminum. For automotive applications, the first composite drive shaft was developed by the Spicer U-Joint division of Dana Corporation for Ford economize van models . When the length of a steel drive shaft goes beyond 1500 mm, it is manufactured in two pieces to increase the fundamental natural frequency, which is inversely proportional to the square of the length and proportional to the square root of the specific modulus. The nature of composites, with their higher specific elastic modulus, which in carbon/epoxy exceeds four times that of aluminum, enables the replacement of the two-piece metal shaft with a single-component composite shaft which resonates at a higher rotational speed, and ultimately maintains a higher margin of safety. A composite drive shaft offers excellent vibration damping, cabin comfort, reduction of wear on drive train components and increases tire traction. In addition, the use of single torque tubes reduces assembly time, inventory cost, maintenance, and part complexity .Graphite/carbon/fiberglass/aluminum drive shaft tube was developed as a direct response to industry demand for greater performance and efficiency in light trucks, vans and high performance automobiles. Since carbon fiber epoxy composite materials have more than four times specific stiffness of steel or aluminum materials, it is possible to manufacture composite drive shaft s in one-piece.

II. BASIC CONCEPTS OF COMPOSITE MATERIALS

Composite materials have been widely used to improve the performance of various types of structures. Compared to conventional materials, the main advantages of composites are their superior stiffness to mass ratio as well as high strength to weight ratio. Because of these advantages, composites have been increasingly incorporated in structural components in various industrial fields. Some examples are helicopter rotor blades, aircraft wings in aerospace engineering, and bridge structures in civil engineering applications. Some of the basic concepts of composite materials are discussed in the following section to better acquaint ourselves with the behaviour of composites.

Composite materials are basically hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a single structural material. The constituents are combined at a macroscopic level and are not soluble in each other. The key is the macroscopic examination of a material wherein the components can be identified by the naked eye. Different materials can be combined on a microscopic scale, such as in alloying of metals, but the resulting material is, for all practical purposes, macroscopically homogeneous, i.e. the components cannot be distinguished by the naked eye and essentially acts together. The advantage of composite materials is that, if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses. Some of the properties that can be improved by forming a composite material are strength, fatigue life, stiffness, temperature-dependent behaviour, corrosion resistance, thermal insulation, wear resistance, thermal conductivity, attractiveness, acoustical insulation and weight. Naturally, not all of these properties are improved at the same time nor is there usually any requirement to do so. In fact, some of the properties are in conflict with one another, e.g., thermal insulation versus thermal conductivity. The objective is merely to create a material that has only the characteristics needed to perform the designed task. There are two building blocks that constitute the structure of composite materials. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibres, particulates, flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel, epoxy reinforced with graphite fibres, etc

III. FIBRES

Fibres are the principal constituent in a fibre-reinforced composite material. They occupy the largest volume fraction in a composite laminate and share the major portion of the load acting on a composite structure. Proper selection of the type, amount and orientation of fibres is very important, because it influences the following characteristics of a composite laminate.

- Specific gravity
- Tensile strength and modulus
- Compressive strength and modulus
- Fatigue strength and fatigue failure mechanisms
- Electric and thermal conductivities
- Cost

The various types of fibres currently in use are

- Glass Fibres
- Carbon Fibres
- Aramid Fibres
- Boron Fibres
- Silicon Carbide Fibres

IV. CLASSIFICATION OF COMPOSITES

Composite materials in general are categorised based on the kind of reinforcements or the surrounding matrix. There are four commonly accepted types of composite materials based on reinforcements

a) Fibrous composite materials that consist of fibres in a matrix.
b) Laminated composite materials that consist of layers of various materials.
c) Particulate composite materials that are composed of particles in a matrix.
d) Combinations of some or all of the first three types.

And the major composite classes based on structural composition of the matrix area.

a) Polymer-Matrix Composites
b) Metal- Matrix Composites
c) Ceramic- Matrix Composites
d) Carbon- Carbon Composites
e) Hybrid Composites

V. APPLICATIONS OF COMPOSITE MATERIALS

The common applications of composites are extending day by day. Nowadays they are used in medical applications too. Some other fields of applications are,

Automotive : Drive shafts, clutch plates, fibre Glass/Epoxy leaf springs for heavy trucks and trailers, rocker arm covers, suspension arms and bearings for steering system, bumpers, body panels and doors.

Aerospace: Drive shafts, rudders, elevators, bearings, landing gear doors, panels and floorings of airplanes, payload bay doors, remote manipulator arm, high gain antenna, antenna ribs and struts etc.

Marine: Propeller vanes, fans & blowers, gear cases, valves &strainers, condenser shells.

Chemical Industries: Composite vessels for liquid natural gas for alternative fuel vehicle, racked bottles for fire service, mountain climbing, underground storage tanks, ducts and stacks etc.

Electrical & Electronics: Structures for overhead transmission lines for railways, Power line insulators, Lighting poles, Fibre optics tensile members etc.

VI. DRIVE SHAFT

As mentioned above, recent developments in the applications of composite materials have shown that a composite material structural member used in power transmission can be of a great assistance in overcoming a few of the problems faced with conventional drive shafts. The assessment of the extent of this fact is the essence of this work. Therefore a good understanding of the drive shaft would be a prerequisite and is discussed in the following section. A drive shaft, propeller shaft (prop shaft), or Cardan shaft is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them. Drive shafts are carriers of torque. They are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia. Therefore a drive shaft is expected to function, as follows.

a) It must transmit torque from the transmission to the differential gear box.
b) The drive shaft must also be capable of rotating at very high speeds as required by the vehicle.
c) The drive shaft must also operate through constantly changing angles between the transmission, the differential and the axels.
d) The length of the drive shaft must also be capable of changing while transmitting torque. Thus the design of a drive shaft presents itself as a case of torsion problem. Further, with regard to the conventional drive shafts following shortcomings were observed some of which could be addressed better with a composite shaft.

They have less specific modulus and strength

i. Increased weight
ii. Conventional steel drive shafts are usually manufactured in two pieces to increase the fundamental bending natural frequency because the bending natural frequency of a shaft is inversely proportional to the square of beam length and proportional to the square root of specific modulus. Therefore the steel drive shaft is made in two sections connected by a support structure, bearings and Ujoints and hence overall weight of assembly will be more.
iii. Its corrosion resistance is less as compared with composite materials.

iv. Steel drive shafts have less damping capacity. Since a drive shaft is a case of torsion problem an understanding of the methodology of solving such a problem in structural mechanics is necessary.

VII. TORSION PROBLEM IN STRUCTURAL MECHANICS

Torsion of cylindrical shafts has long been a subject of interest in power transmission problems. To this end the stiffness of a cylindrical shaft under torsional loading is considered. The axial displacement field of the cross-section is assumed not to vary along the axial direction away from the ends of the shaft. Under this assumption, the torsional rigidity is only dependent on the shape of the cross-section. The governing equations of this boundary value problem can be formulated in terms of a Laplace or Poisson Equation. Within the former one, one uses the warping function as dependent variable, while in the latter the Prandtl's stress function is used. The solutions for the warping and Prandtl's stress function have been obtained exactly for simple cross-sectional shapes such as a circle, annulus, ellipse, rectangle, and triangle. For more complicated shapes, numerical methods are usually employed, such as, the finite difference method, finite element method and boundary element method. Some authors use the approach of combination of experimental and analytical methods to predict the effective in-plane and outof-plane shear moduli of structural composite laminates. Due to the extensive use of composite materials, the study of compound bars under torsion has become a point of focus in the recent days.

VIII. TORSION OF COMPOSITE SHAFTS

Compared to homogeneous cylindrical shafts, the torsional behaviour of composite shafts is considerably more complicated. The torsional rigidity not only depends on the global crosssectional geometry, but also on the properties and configurations of each constituent. The analytical solution of compound bars under torsion was first obtained by Muskhelishvili (1963), where the solution was expressed in terms of eigen functions. PackhamandShail (1978) used linear combinations of solutions of a homogeneous shaft to solve the problem in which the cross section is symmetric with respect to the common boundary. The elastic properties of non-homogeneous anisotropic beams are usually of engineering interest. Torsional rigidities of multilayered composite beams are especially needed when structures are under torsional loading.

Savoia and Tullini (1993) analyzed the torsional response of composite beams of arbitrary cross section. The boundary value problem was formulated in terms of both warping and Prandtl's stress function. Using the eigen function expansion method, the exact solution of rectangular multilayered orthotropic beams under uniformtorsion was derived. Swanson (1998) extended the existing solutions of torsion of orthotropic laminated rectangular beams to the high aspect ratio case. Based on the membrane analogy, an approximate solution of general, thin, laminated, open cross sections was derived. In this study, an analytical approach is proposed to solve the torsion problem of laminated composite shafts that consist of orthotropic sublaminates. The present approach uses the concept of elastic constants (Chou, et al., 1972), in which the threedimensional nonhomogeneous orthotropic laminate is replaced by an equivalent homogeneous orthotropic material.

A small element consisting of n layers from the composite material, [assumed to represent the behaviour of the overall composite laminate] is considered to be under a uniform state of stress when the composite laminate is under arbitrary loading. Two assumptions have been made in this regard: first, the normal strains and shear strains parallel to the plane of layers are uniform and the same for each constituent and the corresponding stresses are averaged. Second,

The normal stresses and shear stresses perpendicular to the plane of layers are uniform and equal for each constituent and the corresponding strains are averaged. Under these two assumptions, the equilibrium at each sublaminate interface and compatibility conditions of materials are satisfied automatically. As the thickness of each layer approaches zero, the overall effective elastic constants are developed. The effective shear moduli of the composite laminates are used to calculate the overall torsional rigidity of the orthotropic laminated shaft. Having convinced ourselves about the nature of the problem and the possible solution to it, we now move on to develop a better understanding of the fundamentals necessary for the present work. A qualitative literature survey would greatly help us achieve it and is presented in the following chapter.

IX. ANALYSIS OF COMPOSITE DRIVE SHAFT

A good design solution can be delivered only when the function of the component being designed, is known before hand with proper working condition specifications. Ability of different methodologies in solving for these conditions can be appreciated based on the complexity of the problem, though. Presently, the specifications of the composite shaft to be designed are considered to be same as that of an optimally designed steel shaft. Comparison is made between the composite and the conventional steel shaft for maximum shear stress induced in the shafts and maximum deflections in the shafts. Finally modal analysis is carried out to study the variation in natural frequency by changing the fibre angle orientation of different layer of the composite shaft.

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XI. STATIC ANALYSIS

A static analysis calculates the effects of the study loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can however, include steady inertia loads (such as gravity and rotational velocity), and time varying loads that can be approximated as static equivalent loads (such as static equivalent wind and seismic loads commonly defined in many building codes).

Static analysis is used to determine the displacement, stresses strains and forces in structural components caused by loads that do not include significant inertia and damping effects. Steady loading and response conditions are assumed i.e. the loads and the structures response is assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

- Entirely applied forces and pressures
- Steady static inertial forces (such as gravity (or) rotational velocity)
- Imposed (non-zero) displacements
- Temperatures (for thermal Strain)
- Fluencies (for nuclear swelling)

A static analysis can be either linear or nonlinear. All types of nonlinearities are allowed- Like large deformations, plasticity, creep, stress, stiffening contact (gap) elements and hyper elastic elements.

MODAL ANALYSIS: Used to calculate the natural frequencies and mode shapes of a structure and different mode extraction methods are available.

BUCKLING ANALYSIS:Buckling analysis is a technique used to determine buckling loads. Critical loads at which the structure becomes unstable and buckled.

- Build Model
- Obtain the static solution
- Obtain the Eigen value buckling solution
- Expand the solution
- Review the results

Buckling analysis is a technique used to determine buckling analysis and element type, material properties; boundary conditions are same as for static analysis except the prestress effects are to be included.

XII. DESIGN SPECIFICATIONS AND MATERIALS

SHAFT SPECIFICATIONS

Radius : 50 mm

Depth : 1850 mm

Thickness : 2 mm

Set	Stacking sequence	No. of layers
1	±45	4
2	$[90/0/90/0/90/45]_s$	11
3	$[0/90/0/90/0/45]_s$	11
4	$[0/90/0/45/90/-45]_s$	11

Mechanical Properties E-glass/epoxy

Ex : 5e4

Ey : 12e3

Ez : 12e3

Poisson's ratio : 0.3

Shear modulus : 5600

Density : 2e-9

Mechanical Properties carbon/epoxy:

Young's modulus, Ex, Ey, Ez: 70e3

Poisson's ratio : 0.3

Shear modulus : 5e3

Density : 1.6e-9

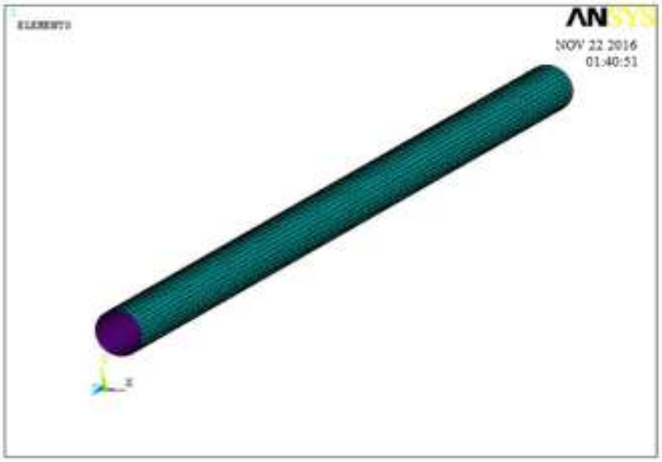
VIII. DESIGN ANALYSIS

Finite element analysis is a computer based analysis technique for calculating the strength and behavior of structures. In the FEM the structure is represented as finite elements. These elements are joined at particular points which are called as nodes. The FEA is used to calculate the deflection, stresses, strains temperature, buckling behavior of the member. In our project FEA is carried out by using the ANSYS 12.0. Initially we don't know the displacement and other quantities like strains, stresses which are then calculated from nodal displacement.

Static analysis 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, Externally applied forces, moments and pressures Steady state inertial forces such as gravity and spinning Imposed non-zero displacements. 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 itself. To avoid such a failure, this analysis is necessary.

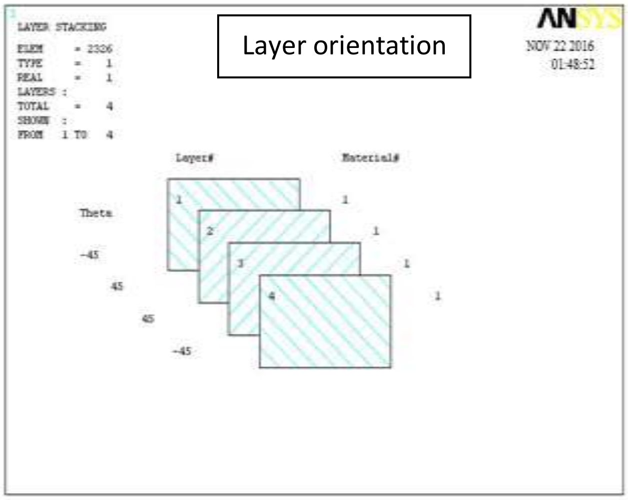
IX. RESULTS & DISCUSSIONS

EGLASS/EPOXY:

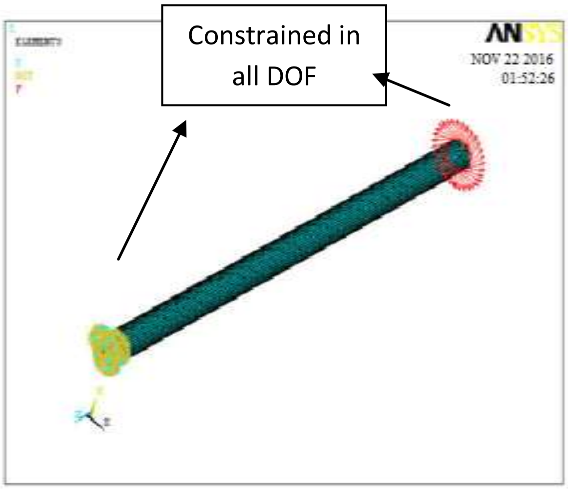


Element type: shell99

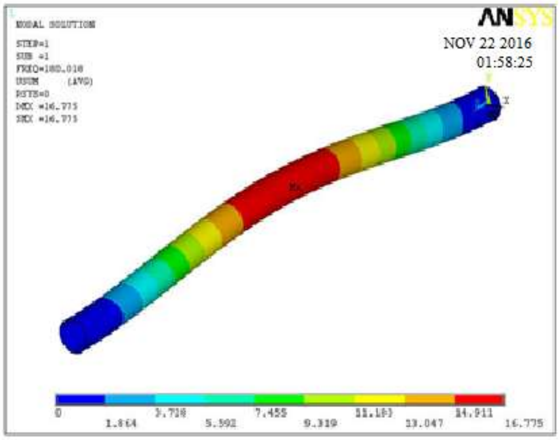
Total no. of elements: 5920



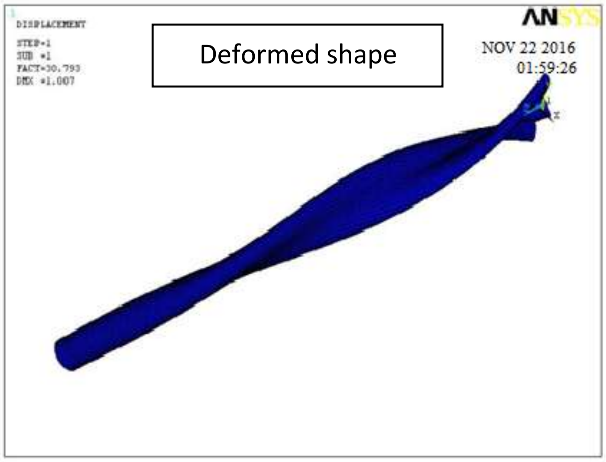
Modal analysis:

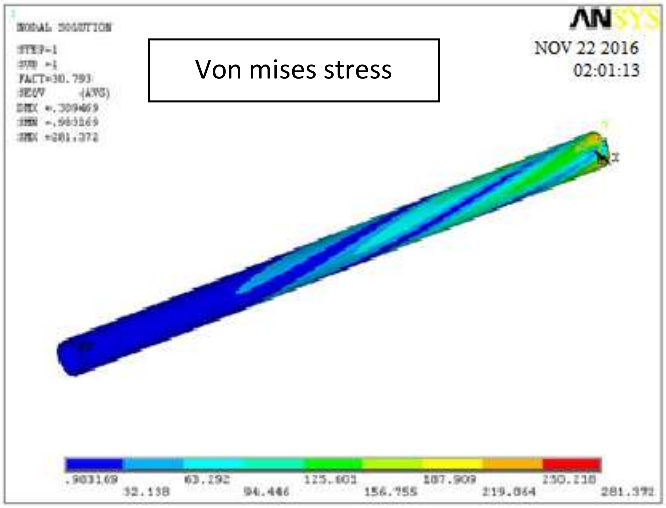


Mode shape at fundamental natural frequency



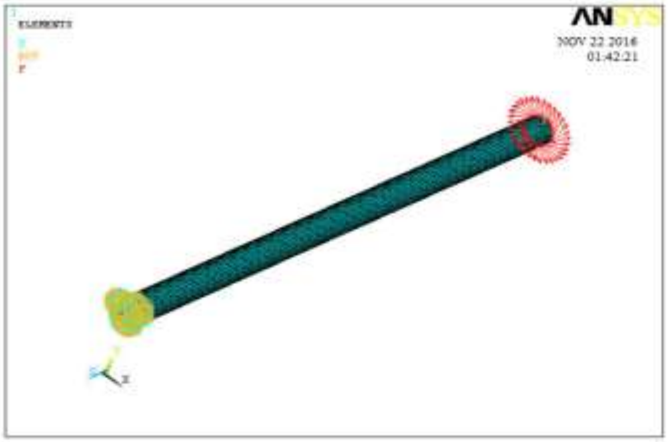
Buckling:



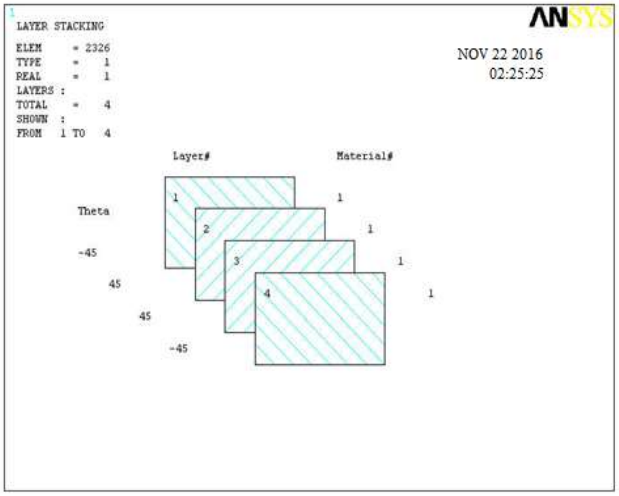


CARBON/EPOXY:

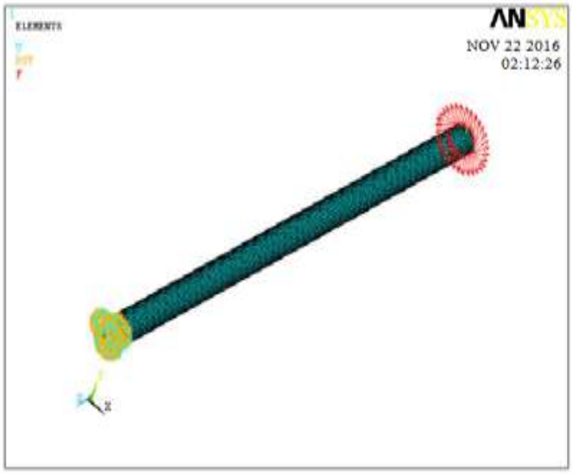
Finite element model:

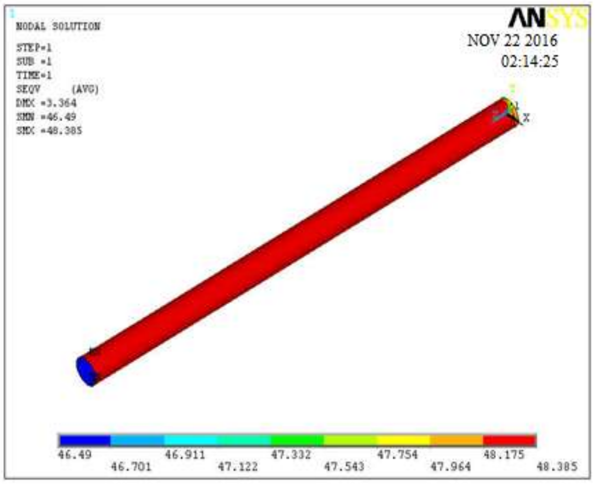


Element type: shell99Total no. of elements: 5920

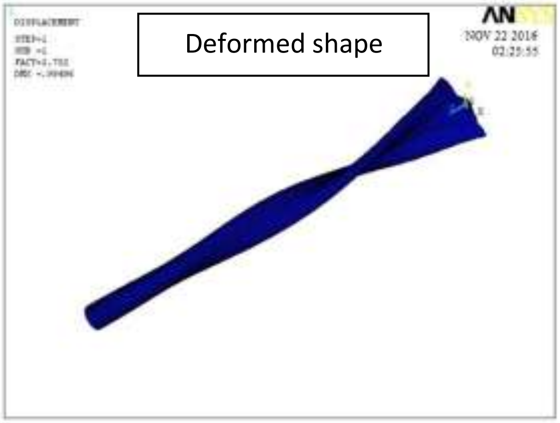


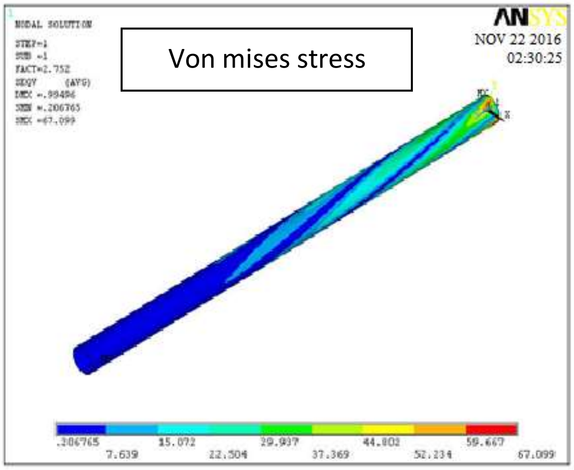
Modal analysis:





Buckling:





CONCLUSION

Stresses developed in the Eglass/epoxy are within the allowable stresses, Weight of the driveshaft made up of Eglass/epoxy is low, comparing with carbon/epoxy.

Weight of the carbon/epoxy driveshaft is very less, comparing with Eglass/epoxy. Total deflection and frequency are less.

Stresses developed in the carbon/epoxy are within the yield strength. Weight of the carbon/epoxy driveshaft is same as the weight of the carbon/epoxy driveshaft, and lower than the other two materials. Von mises stresses in the buckling are high.

Comparing the driveshaft with Two materials and plies orientations, we can conclude that, Eglass/epoxy of can withstand all the applied loads. Even though weight of the

Eglass/epoxy driveshaft is little bit higher, it is suggestible material for the driveshaft is Eglass/epoxy

REFERENCES

1. AmitAherwar, (2012),"Vibration Analysis Techniques for Gearbox Diagnostic: a review".
2. Ebersbach et al, (2005), “The investigation of the condition and faults of a spur gearbox using vibration and wear debris analysis techniques”, international conference on wear of materials".
3. Decker Harry. J (2002), “Gear Crack detection using tooth analysis at NASA Research Center”
4. M. Sofian ,D. Hazry ,K. Saifullah ,M. Tasyrif, K.SallehI.Ishak,(2009) "A study of Vibration Analysis for Gearbox Casing Using Finite Element Analysis".
5. Pratik Gulaxea, N. P. Awate,(2013)"Design, modeling & analysis of Gear box for material handling trolley: a review"
6. G Diwakar, Dr. M R S Satyanarayana, P. Ravi Kumar,(2012)"Detection of Gear fault using vibration analysis"
7. L. Deshpande ,N. Sawalhi and R.B. Randall(2011) "Gearbox Fault Simulation using Finite Element Model Reduction Technique"
8. Jiri Tuma,(2009) "GearboxNoiseandVibrationPredictionandControl"
9. Endo Hiroaki and Sawalhi Nader,(2012) "Gearbox Simulation Models with Gear and Bearing Faults "

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