DESIGN AND ANALYSIS OF COMPOSITE DRIVE SHAFT (GLASS FIBER)

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Abstract :This study deals with Design and Optimization of Composite drive shaft using Ansys considering structure under static loading. Continuous technological advances in engineering design field result in finding the alternate solution for the conventional materials. Conventional shaft is made of steel, which has many disadvantages like low specific stiffness and strength. Hence in this study we have designed and analysed composite drive shaft. CAE analysis has been done different thickness of hollow composite shaft and experimental validation is also carried out to arrive at the conclusion. Optimization methods were developed to have lighter, less cost and may have better strength too. This paper discussed the work carried out on composite shaft using Ansys.

KeyWords - **Design, Optimization, Static Load, Composite, Driveshaft, CAE, Ansys.**

Introduction:

1. Introduction

Continuous technological advances in engineering design field result in finding the alternate solution for the conventional materials. The design engineers arrivedto a point to finding the materials which are better than conventional materials. Researchers and designers are constantly looking for the solutions to provide stronger and durable materials which will answer the needs of fellow engineers. Propeller shafts or Drive shafts are used for transmitting the power in many applications, including pumping sets, aerospace, trucks, cooling towers, and automobiles. In the design of metallic shaft, knowing the torque from the reverse engineering and the allowable shear stress for the material, the size of the shaft's cross section can also be determined. In the today's world there is a heavy requirement for lightweight materials vehicle.

1.1 Functions of Drive shaft:

This is the shaft which transmits the drive from the transmission system (gear box) to the rear axle through differential.
The main functions are:

- Transmit the power from gear box
- To compensate for change in length: The length of the drive shaft must also be capable of changing while transmitting torque. Length changes are caused by axle movements due to torque reaction, road deflections, braking load and so on. A slip joint is used to composite for this motion. The slip joint is usually made of an internal and external spline. It is located on front end of the drive shaft and is connected to the transmission.
- Transmit motion at an angle which is varying frequently: The drive shaft must also operate through constantly changing angles between the transmission, the differential and the axles. As the rear wheels roll over bumps in the road, the differential and the axle move up and down
- The drive shaft must also be capable of rotation at the very fast speeds required by the vehicle.

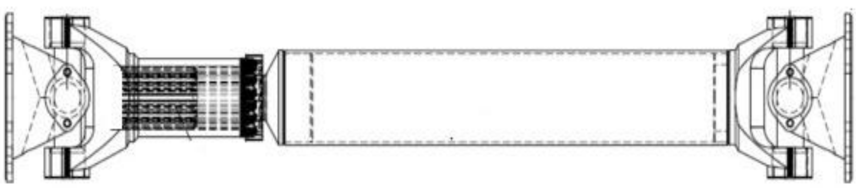


Fig.1: general view of a drive shaft

2. Problem Statement

Conventional steel drive shafts are usually manufactured with mild steel and they have less specific modulus and strength. It's corrosion resistance is less as compared with composite materials, Increased weight, Steel drive shafts have less damping capacity.Hence to reduce weight of shaft and to increase its efficiency here an attempt has made by considering glass fiber which have high specific modulus, strength, damping capacity and corrosion resistance as compared with existing steel materials. Existing drive shaft functionality is studied and analyzed initially later material optimization technique will be adopted through iteration until getting best fitting model.

3. Introduction to composites

Composite materials are made of combination of materials, which are combined together to achieve specific structural properties. Every material do not merge completely in the composite, but they act work as one. The components are physically identified as they interface with one another. The properties of the composite material are superior to the properties of the individual materials from which it is constructed.Anlatest composite material is made of a fibrous material embedded in a resin matrix, generally laminated with fibers oriented in alternating directions to give the material strength and stiffness.

An isotropic material has uniform properties in all directions. The measured properties of an isotropic material are independent of the axis of testing. Metals such as aluminum and titanium are examples of isotropic materials.A fiber is the primary load carrying element of the composite material. The composite material is only strong and stiff in the direction of the fibers. Unidirectional composites have predominant mechanical properties in one direction and are said to be anisotropic, having mechanical and/or physical properties that vary with direction relative to natural reference axes inherent in the material. Components made from fiber reinforced composites can be designed so that the fiber orientation produces optimum mechanical properties, but they can only approach the true isotropic nature of metals, such as aluminum and titanium.

A matrix supports the fibers and bonds them together in the composite material. The matrix transfers any applied loads to the fibers, keeps the fibers in their position and chosen orientation, gives the composite environmental resistance, and determines the maximum service temperature of a composite.

3.1.1. Strength Characteristics:

Structural properties, such as stiffness, dimensional stability, and strength of a composite laminate, depend on the stacking sequence of the plies. The stacking sequence describes the distribution of ply orientations through the laminate thickness. As the number of plies with chosen orientations increases, more stacking sequences are possible. For example, a symmetric eight-ply laminate with four different ply orientations has 24 different stacking sequences.

3.1.2. Fiber Orientation:

The strength and stiffness of a composite buildup depends on the orientation sequence of the plies. The practical range of strength and stiffness of carbon fiber extends from values as low as those provided by fiberglass to as high as those provided by titanium. This range of values is determined by the orientation of the plies to the applied load. Proper selection of ply orientation in advanced composite materials is necessary to provide a structurally efficient design. The part might require 0° plies to react to axial loads, ±45° plies to react to shear loads, and 90° plies to react to side loads. Because the strength design requirements are a function of the applied load direction, ply orientation and ply sequence have to be correct. It is critical during a repair to replace each damaged ply with a ply of the same material and ply orientation.

3.2. Glass fiber:

Composite materials are basically hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a single structural material. Various scientific definitions for composite materials can be expresses as follows;

- The word composite means made up of two or more parts. A composite material is one made of two other materials. The composite material then has the properties of the two materials that have been combined.

- Composites, which consist of two or more separate materials combined in macroscopic structural unit, are made from various combinations of the other tree materials.

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 act 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 behavior
- Corrosion resistance -thermal insulation
-Wear resistance -thermal conductivity
-Attractiveness -acoustical insulation
-weight

Glass Fibers: Glass fibers with polymeric matrices have been widely used in various commercial products such as piping, tanks, boats and sporting goods. Glass is by far the most widely used fiber, because of the combination of low cost, corrosion resistance, and in many cases efficient manufacturing potential. It has relatively low stiffness, high elongation, and moderate strength and weight, and generally lower cost relative to other composites. It has been used extensively where corrosion resistance is important, such as in piping for the chemical industry and in marine applications. It is used as a continuous fiber in textile forms such as cloth and as a chopped fiber in less critical applications. (Swanson S.R; 1997; 3) Glass fibers are strong as any of the newer inorganic fibers but they lack rigidity of on account of their molecular structure. The properties of glasses can be modified to a limited extent by changing the chemical composition of the glass, but the only glass used to any great extent in composite materials is ordinary borosilicate glass, known as E-glass. E glass is available as continuous filament, chopped stable and random fiber mats suitable for most methods of resin impregnation and composite fabrication. S glass, originally developed for aircraft components and missile casings, has the highest tensile strength of all fibers in use. However, the compositional difference and higher manufacturing cost make it more expensive than E-glass. A lower cost version of S glass, called S-2 glass, has been made available in recent years. Although S-2 glass is manufactured with less stringent nonmilitary specifications, its tensile strength and

modulus are similar to those of S-glass. S-glass is primarily available as ravings and yarn and with a limited range of surface treatments. S-glass fibers are being used in hybrid reinforcement systems in combination with graphite fibers and aramid fibers. R-glass is a similar high-strength, high modulus fiber developed in France.
Glass fibers are also available in woven form, such as woven roving and waving cloth. Woven roving is coarse, droppable fabric in which continues ravings are woven in two mutually perpendicular directions.

Property	Value
Young's modulus in x-direction, E_x	40300 MPa
Young's modulus in y-direction, E_y	6210 MPa
Young's modulus in z-direction, E_z	40300 MPa
Poisson's Ratio ,ν	0.2
Density, ρ	1.9×10^{-9} tonne/mm^3
Shear modulus in XY plane	3070 MPa
Shear modulus in YZ plane	2390 MPa
Shear modulus in ZX plane	1550 MPa

Table 1: Material properties of Glass fibers

4. Design of hollow Steel shaft.

A vehicle with a manual transmission uses a clutch to engage and disengage the engine from the drive train.
Engine torque is transmitted through the clutch to the transmission or transaxle. The transmission contains sets of gears that increase or decrease the torque, before it is transmitted to the rest of the drive train. The lower the gear ratio selected, the higher the torque transmitted.
A vehicle starting from rest needs a lot of torque, but once it is moving, it can maintain speed with only a relatively small amount of torque. A higher gear ratio can then be selected, and engine speed reduced.
A conventional vehicle with the engine at the front and driving wheels at the rear, uses a drive shaft, called a propeller shaft, to transmit torque from the transmission to the final drive.

4.1 Torque Calculation.

Torque available at drive shaft is given by:
Engine torque X transmission ratio X final drive ratio……………. (1)

Engine type	2.5L MDI Turbocharged Diesel Engine
Displacement	2523cc
Power	81.9bhp @3200rpm
Torque	150Nm@1500rpm
Valve mechanism	NA
Cylinder configuration	NA

Table.2: Engine specification

I	3.78:1
II	2.09:1
III	1.38:1
IV	1.00:1
V	0.79:1
reverse	3.53:1

Gear Ratios

I	3:1
II	2:1
III	1.5:1
IV	1:1
V	0.75:1

Transmission ratios

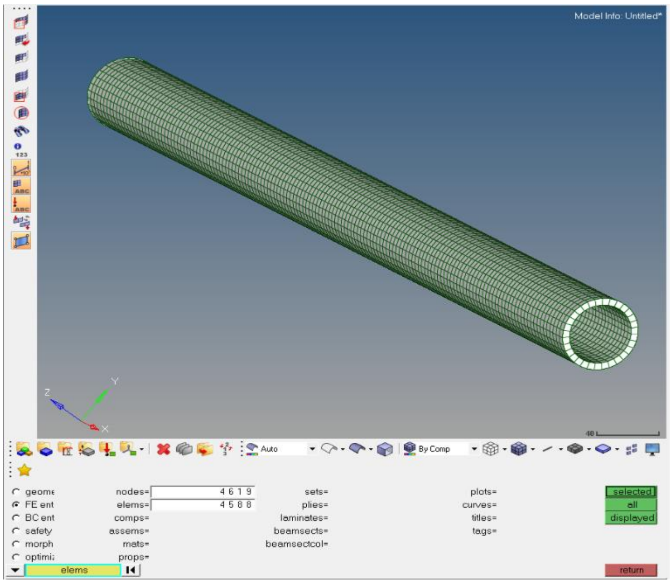
Table:3 Gear and Transmission ratios

Putting above values in eq (1), we get:

$\therefore T = 150 \times 3.78 \times 3$

T≅1700 Nm

CAE of hollow steel shaft.



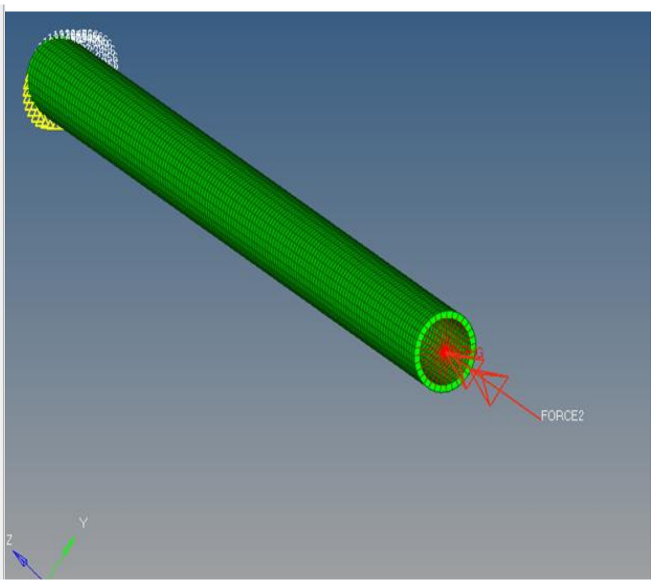
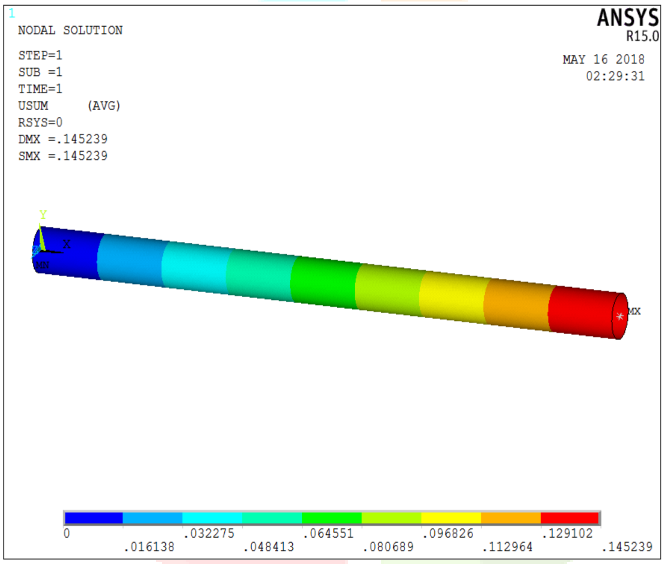


Fig 2: Meshed model Fig3:Meshed model with applied boundary condition



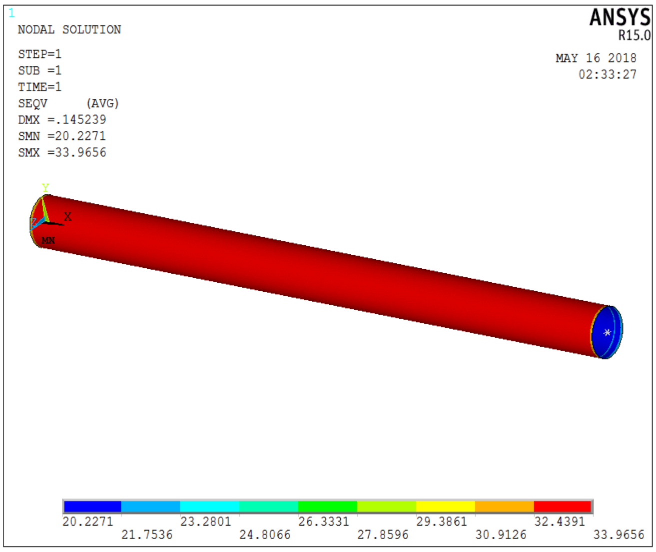


Fig 4: Maximum deformation of 0.1452 mm observed Fig 5: Maximum stress of 33.965 Mpa observed

Values of maximum deformation and maximum stresses are noted for further comparison of results.

5. Design of hollow Composite (Glass Fiber) shaft.

Here regular 5 mm thick walled steel Drive Shaft is replaced with 5 mm composite material (Glass fiber). Considering same boundary conditions as above.

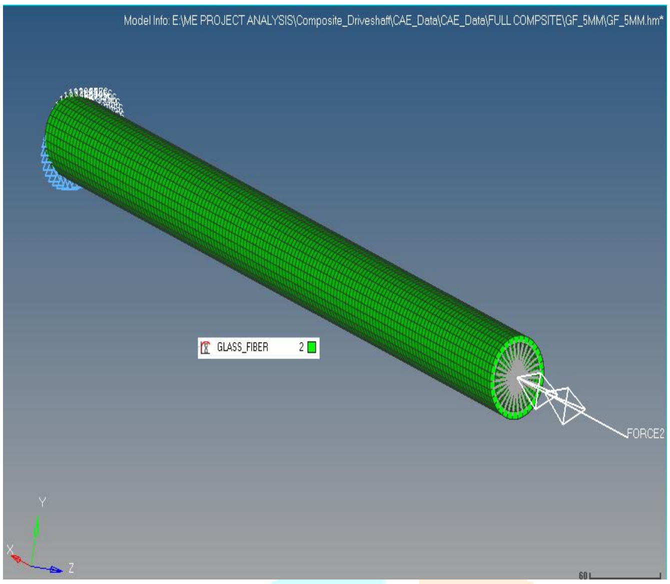


Fig 6: Meshed model with composite material allocation and boundary conditions

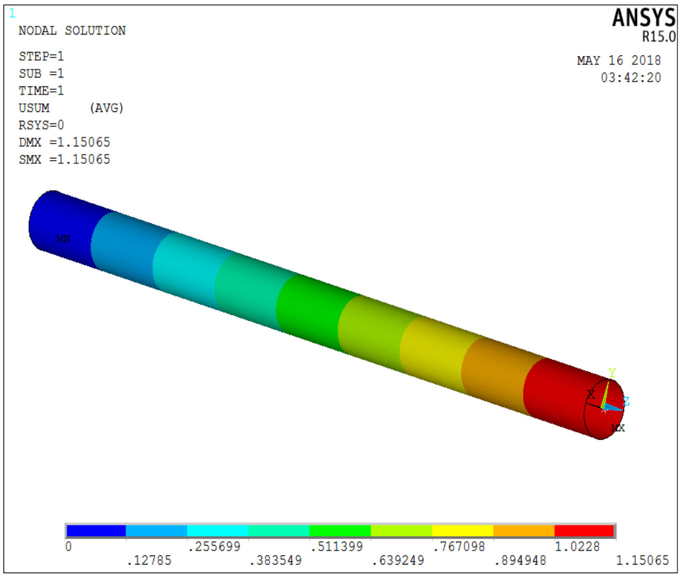


Fig 7: Maximum deformation of 1.15 mm observed

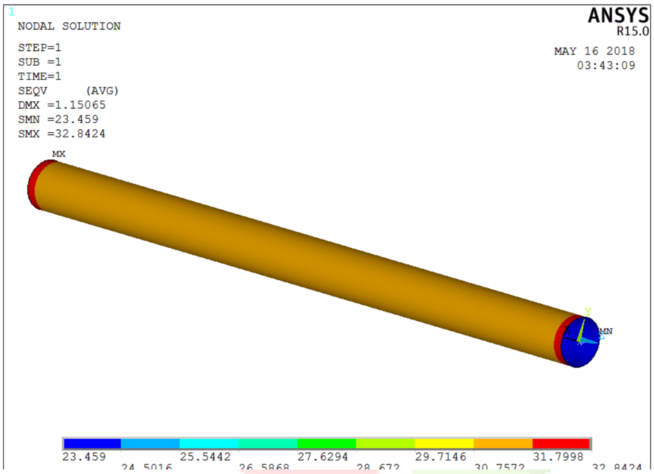


Fig 8: Maximum stress of 32.842 Mpa observed

- For 5mm thickness the maximum deformation of 1.15 mm is observed
- In the composite drive shaft seems which is very high and leads to plastic deformation.
- Hence 5mm leads to unstable design and there is need for increment in strength which is achieved through increment in shaft thickness.
- Optimization of shaft thickness is required.

6. Optimization of shaft thickness.

Iteration 1: Shaft Thickness 7mm.

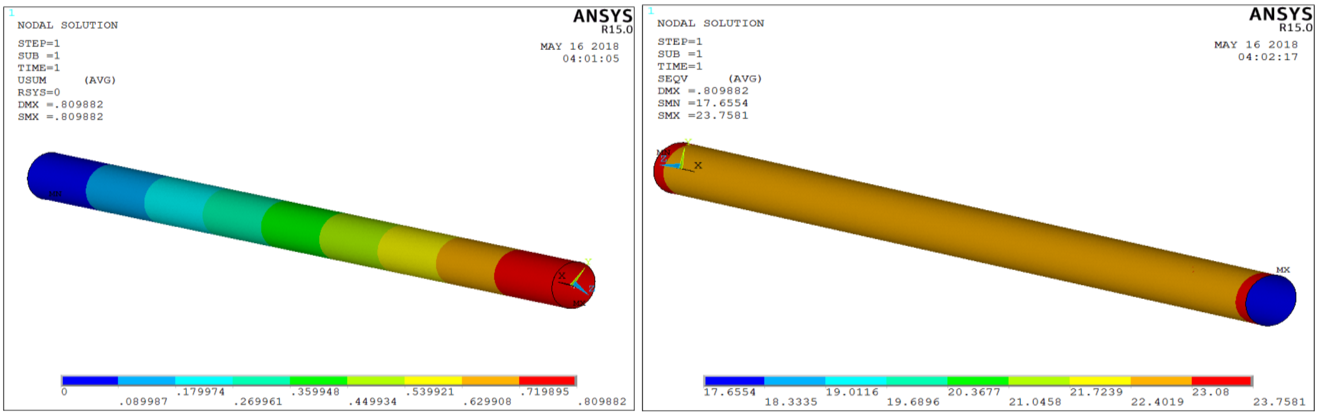


Fig 9: The maximum deformation of 0.809mm observed and Maximum stress of 23.758 Mpa observed

Iteration 2: Shaft Thickness 9mm.

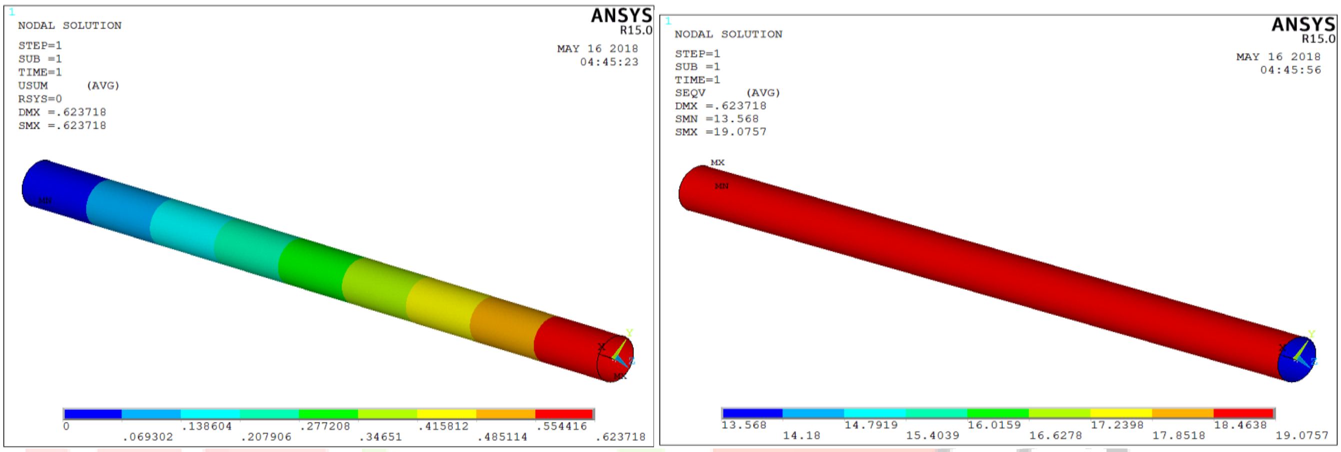


Fig 10: The maximum deformation of 0.623 mm observed and Maximum stress of 19.07 Mpa observed

Iteration 3: Shaft Thickness 10mm.

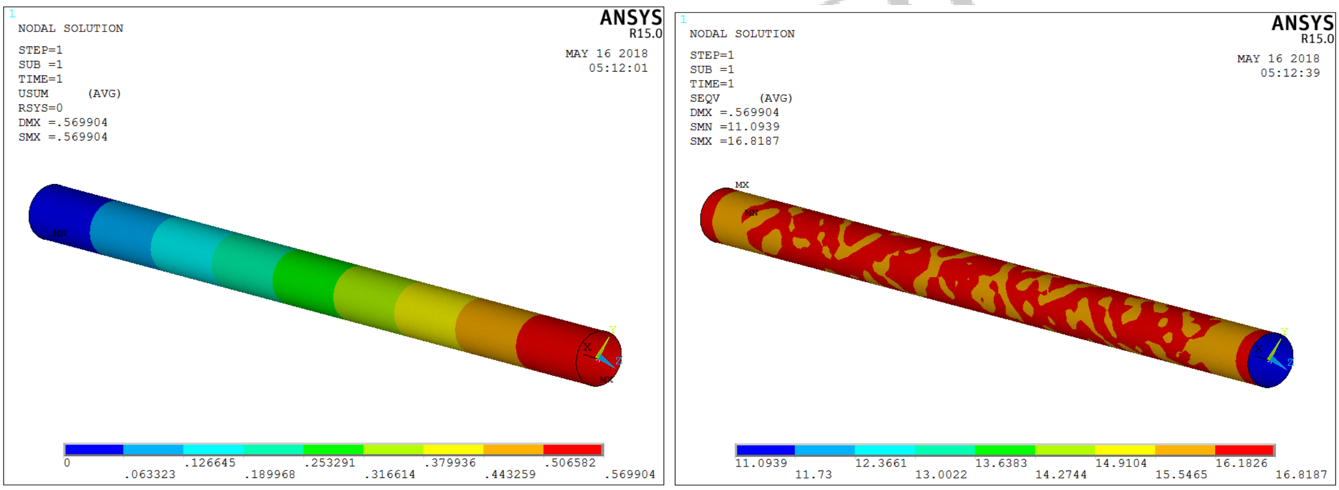


Fig 11: The maximum deformation of 0.569 mm observed and Maximum stress of 16.81 Mpa observed

7. Study of Deformation using experimental setup.

Testing of composite glass fiber drive shaft has done in universal testing machine. Same loading conditions of shaft fixing at one end and torque of $1.7*10^6$ N-mm has applied on the other end as considered in Finite Element Analysis with proper design of fixtures as shown below.
The force is been vertically applied at 22.5^o with respect to base orientation origin of glass fiber with is at 45^o

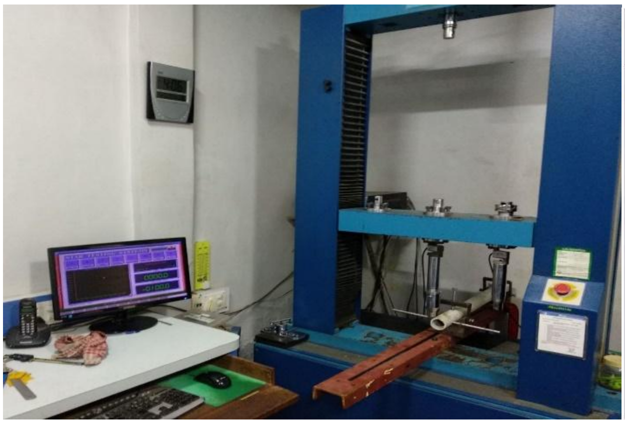


Fig 12 : Experimental Setup

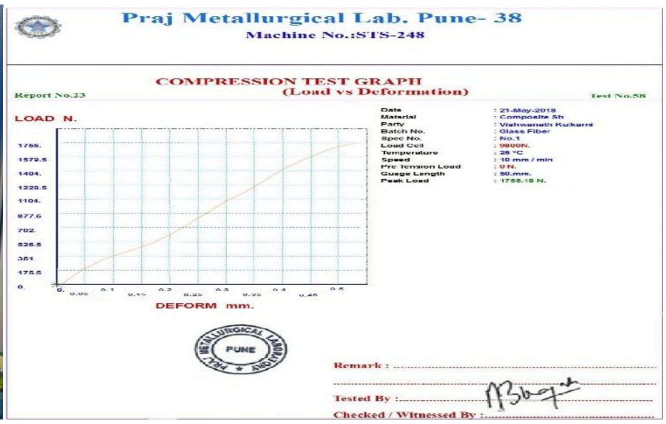


Fig 13: Deformation output graph

8. Result and discussion.

Deformation Comparison.

Test type	Deformation (mm)	% Error in Result
FEA Method	**0.569**	**5.09**
Experimental Method	**0.54**	

Table.4: Comparison of FEA and Experimental results for deformation

From the Experimental test plot Deformation of around **0.54 mm** has observed for the applied loadings with is almost nearer to FEA results of **0.569 mm** hence the results are in well arrangements.

9. Conclusion and Future scope.

- Experimental results are in well arrangement with FEA results with error of 5.09%
- Weight has been reduced approximately by 70% because of density of glass fiberand topology remains the same
- Mechanical strength has been increased considerably
- Rust free operation.

9.1 Future scope

- Better vibration damping which can be studied further
- Study on different composites like carbon fiber drive shaft can be made for increased structural and mechanical properties.
- Vibration, fatigue behaviors can be studied further

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