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EXPRIMENTAL AND NUMERICAL ANALYSIS OF UNIVERSAL JOINT YOKE

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Abstract:

Universal joint is a joint in a rigid rod that allows the rod to bend in any direction, and is commonly used in shafts that transmit rotary motion. It generally consists of two hinges located close together, oriented at 90^0 to each other, connected by a cross shaft. It is widely used in industrial applications and vehicle drivelines to connect misaligned shaft. Automobile industries are exploring composite material in order to obtained reduction of weight without significant decrease in vehicle quantity and reliability. This is due to the fact that the reduction of weight of vehicle directly proportional to fuel consumption. Universal joint yoke have certain modification are made in existing geometry and analyzing for the identical boundary condition. Thus in this paper the aim is to replace universal joint by composite material. The following material can be chosen are carbon/epoxy composite, Kevlar/epoxy composite. Analysis and experimentation is being performed on universal joint yoke.

Keyword-*Universal joint yoke, composite material, weight reduction, torsional strength.*

I. INTRODUCTION

The power transmission system is the system which causes movement of vehicles by transferring the torque produced by the engines to the wheels after some modifications. The transfer and modification system of vehicles is called as power transmission system. The power transmission system of vehicles consists of several components which encounter unfortunate failures. These failures may be attributed to material faults, material processing faults, Manufacturing and design faults, etc. A major problem with the use of a Hooke's joint is that it transforms a constant input speed to a periodically fluctuating one. The kinematical consequences of this property of this joint can be remedied, as long as rigid body rotations are concerned, by using two converses Hooke's joint. But if torsional vibrations of the propeller shaft are concerned, there is no way of removing the dynamical consequences of an introduced Hooke's joint in a rear wheel drive vehicle. Figure 1 shows the schematic diagram of universal joint. In a widely used single piece drive shaft, two universal joints are used. Two universal joints are preferred in order to avoid the transformation of constant input speed into a fluctuating speed which is encountered when a single universal joint is used.

In 300BC Greek invented universal joint from historical evidence. The name cordon the Italian mathematician utilizes a similar mechanism to suspend a ship compass horizontal, regardless of ship movement. Mr.Harshal Bankar (2013) studied that the composite material has high specific modulus, strength and less weight. The fundamental natural frequency of composite material can be twice as that of steel and aluminum because composite material have more than 4 times specific stiffness which makes it possible to manufacturing the universal joint. Composite material have good corrosion resistance, greater torque capacity and longer fatigue life than steel[1]. Swati Datey (2014) studies each automobile has different power transmission system constructive feature depends upon vehicle drive line concept. While transmitting a torque different stresses are induces such as tension stress and bending stress are experience.[2]

Finite element analysis method is used as stress analysis to determine the stress condition at failed section. Siraj mohammad ali sheikh (2012)studied that drive shaft are generally subjected to torsional stress and bendind stress due to weight of component ,thus these rotataing component are susceptiable to fatigue by the nature of their operation common sign of drive shaft.fatigue is vibration or shudder during operation[3].S G Solankhe (2014) studied that the failure of universal joint is occur due to manufacturing and design fault, raw material faults, maintains faults, material processing faults, drivable joint angle, cyclic load to avoids this problem various such as topology optimization method, weight reduction method, shape optimization method, manufacturing method etc.[4]

II. PROBLEM STATEMENT

The problem for this analysis is taken for the paper of "two cases of failure in the power transmission system on vehicle an universal joint yoke and drive shaft". Universal joint was analyzed in Ansys considering the component to be made up of low alloy steel group(SM45C).typical properties are 1750 MPa as ultimate tensile strength and 1400 MPa as yield strength and 200 nm force applied at spider. The material as well as the loading condition of torsional moment and rotational moment speed kept constant.

A.Objective-

- Comparison between convectional steel joint and composite material joint using Ansys.
- Decide Best material for joint and reduce weight by using composite material.
- To reduce weight and increases torsional strength of the joint.
- To replace the existing Joint material with composite material carbon fibre without affecting natural frequency, stress values & geometry of existing joint.

III. DESIGN CALCULATION

A.Design of Conventional Universal Joint Yoke

Convectional universal joint yoke or composite one, the design should be based on the following criteria:

- Torsional strength
- Torsional buckling and
- Bending natural frequency

SM45C steel was selected, since it is widely used for design of convectional steel shaft. The properties of SM45C steel are:

Young Modulus (E) = 207 Gpa
Shear Modulus (G) = 80 Gpa
Poisson's Ratio (μ) = 0.3
Density of Steel (ρ) = 7600 kg/m^3

Torsional strength

$$\frac{(\tau_{\max})}{F.S} = \frac{(32T\, r_o)}{(\pi[do^4 - di^4])}$$

Where, T =Maximum torque applied in N*M
J = Polar moment of inertia in m^4
d_o and d_i = outer and inner radius of shaft in m

Assuming τ_{max} = 80 Mpa And F.S is 3
T max = 1.8596x10^{-3}

Torsional buckling

A shaft is consider as long shaft, if

$$\left(\frac{1}{\sqrt{1-8^2}}\right)\frac{L^2 t}{(2r)^3} > 5.5$$

$T_b = \tau_{cr}\,(2\pi r^2 t)$

Where the critical stress (τ_{cr}) is given by,

$$\tau_{cr} = \left[\frac{E}{3\sqrt{2}(1-8^2)^{\frac{3}{4}}}\right]\left(\frac{t}{r}\right)^{\frac{3}{2}}$$

Substituting,

τ_{cr} = 81.6875 x 10^7 N/m^2
T_b = 63.11735 x 10^3 N-m

Thus, $T_b > T$

Bending natural frequency

$$F_{nb} = \frac{\pi p^2}{2L^2}\frac{\sqrt{EIx}}{m}$$

Where, m = mass per unit length in kg/m
I_x = moment of inertia in x-direction in m^4

$$I_x = \frac{\pi}{64}(do^4 - di^4)$$

= 3.138 x 10^{-6}m^4

$$M = \rho\left(\frac{\pi}{4}\right)[do^2 - di^2]$$

= 41.949kg/m

Substituting these values,

F_{nb} = 188.806 Hz

Thus,

$F_{nb} > f_{nb\,(min)}$

Thus the designed SMC45 steel driveshaft meets the entire requirement, the total mass of universal joint is:

M = mL
M = 3.23 kg

B.Design of Composite Universal Joint

Only 0°, ± 45° and 90° were considered for the composite ply orientation, owing to their specific advantages.

Design of carbon /Epoxy Universal Joint

60% fiber volume fraction carbon/Epoxy shaft (V_f = 60%) with standard ply thickness of 0.13 mm was selected.

Torsional strength

$$\frac{\tau_{max}}{F.S} = \frac{T}{2\pi r^2 t}$$

Where, r is the mean radius of the shaft.

Since the nature of loading is pure shear, 70% of the plies can be set as ± 45° and the reaming 30% at 0° and 90° orientation.

τ_{max}. = 293 Mpa

For a factor of safety (F.S) of 6,

r^2t = 2.6462 x 10^{-6} m^3

Thus, t ≥1.8106 x 10^{-3}m

Since the thickness of each ply is 0.13 mm

N = 1.8106 x 10^{-3} m/0.13 x10^{-3}
= 13.93 ≅14

Hence the corrected value is

t = 1.82 x10^{-3}m
r_i = 0.009 m
r = 0.027 m

Torsional buckling:-

Considering the hollow composite shaft as an isotropic cylindrical shell, the buckling torque is given by:

$T_b = 2\pi r^2 t\,(0.272)\,(E_x E_y^3)^{1/4}\,(t/r)^{3/2}$

Where,

E_x and E_y are the young modulii in x and y direction respectively.

From figure 5.2

$E_x = 38709.5$ Mpa

By permuting (interchanging the percentages of 0° and 90° plies)

$E_y = 38709.5$ Mpa

Upon substitution,

$T_b = 3067.49$ N-m (>T)

Bending natural frequency:-

$F_{nb} = \pi/2L^2 \frac{\sqrt{ExIx}}{m}$

The density of carbon/Epoxy laminates $(\rho) = 1530$ kg/m^3

Hence,

$Ix = 1.179957 \times 10^{-6} m^4$

$M = 1.03385$ kg/m

Upon substitution,

$F_{nb} = 101.93$ Hz (>80Hz)

The total mass of carbon/Epoxy composite driveshaft is

M = 2.38 kg

Design of Kevlar/Epoxy Universal Joint:-

Setting 70% of the plies in $\pm$ 45° and remaining 30% in 0° and 90° similar to the previous approach from the respective,

$\tau_{max.} = 95$ Mpa

$E_x = 23900$ Mpa

$E_y = 23900$ Mpa

Using factor of safety of 6 for $V_f = 60\%$ and ply thickness = 0.13 mm

$T > 5.5844 \times 10^{-3} m$

$n = 42.96 \cong 44$

The corrected values are

t = 0.00572 m

$r_1 = 0.05428$ m

r = 0.05714 m

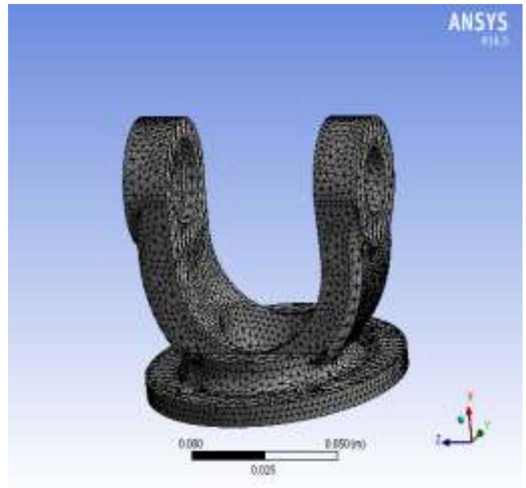
The calculated value of buckling torque, bending natural frequency and the total mass are

$T_b = 24161$ n-m

$F_{nb} = 101.903$ Hz

M = 2.83 kg

IV. SOFTWARE ANALYSIS



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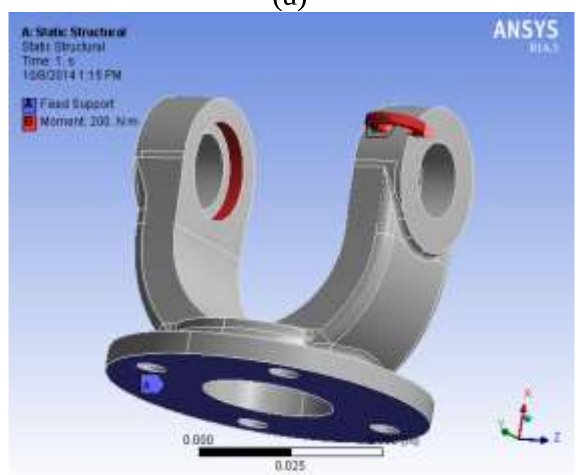

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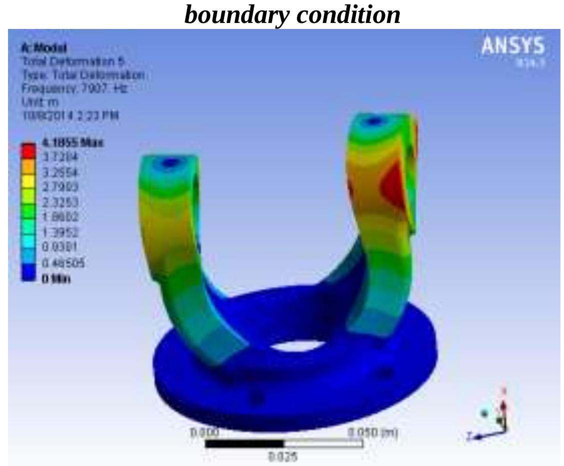
Fig. 1. (a)Modeling of Universal Joint Yoke (b) boundary condition



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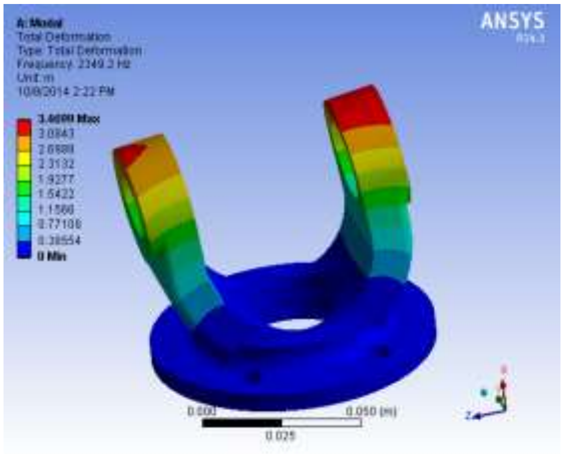

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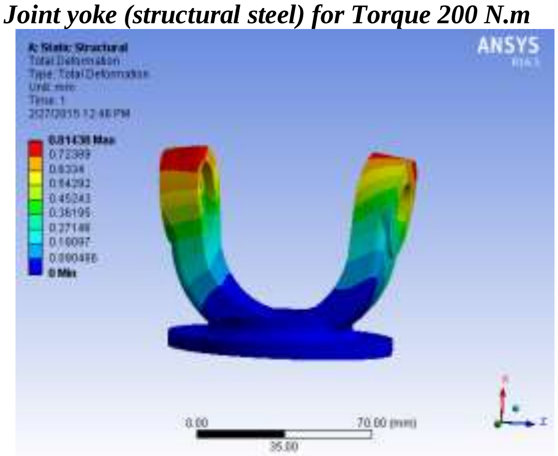
Fig.2. (a) and (b) Total Deformation of universal Joint yoke (structural steel) for Torque 200 N.m



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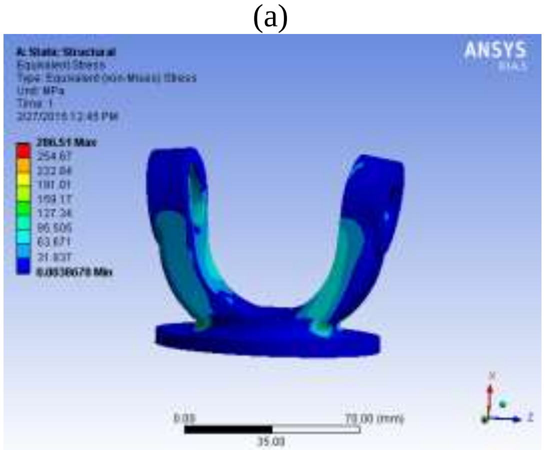
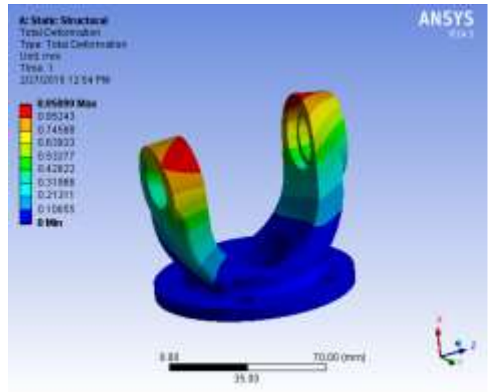


(b)

Fig.3. (a) Total Deformation of Carbon Epoxy Material (b) Von-Misses Stresses in Universal joint Yoke



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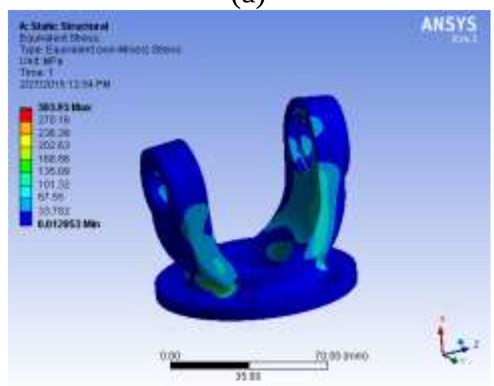

(b)

Fig.4. (a) Total Deformation of Kevlar Epoxy Material (b) Von-Misses Stresses in Universal joint Yoke

V.EXPERIMENTAL VALIDATION

The objective of current work is to determine the torsional strength, stiffness and properties of material. To determine torsional stability the total deformation obtained in yoke is to be measured. For obtaining deformation strain gauge is mounted on chuck of machine. After torsional moment strain gauge will measure the total deformation of the joint. We offer three different technologies of torsion test machines are electromechanical, electrodynamics and servo hydraulic powered. Each torsion testing machine configuration includes a test controller, test software, test table with rotary actuator or motor, power source, torsion test fixtures, and torque and angular position sensors. Our torsion testers are also known as torque testers. Generally four type of torsional testing machine and which is performing the three torsional tests that is static torsion, fatigue torsion, axial torsion and the last is combination of fatigue and station torsion with their calibrating range

First creating a physical prototype of yoke assembly identical in geometry and mechanical properties to the intended component during production, the same is set-up for testing under identical service conditions for the component on field. To simulate the working conditions, the force considered to be applied at the spider mounting location as a torsional moment could be about 200Nm. Torque test result are:

Name of the part-Yoke assembly
Machine type- Torque testing machine
Applied torque- 0 to 200 Nm
Instrument used – Strain gauge

Strain gauge are use to record 'Stress' is chosen at the maximum stress region per the results for Finite element analysis.

VI.RESULT AND DISSCUSSION

The following section discusses the results obtained analytically and practically. The torsional strength and mass of universal joint yoke is calculated theoretically and analytically. For obtaining the torsional strength, the static analysis was carried out using the Ansys 14 version. As discussed earlier, proposed design of carbon fiber material was selected for manufacturing. Because it is more preferable, and it's good torsional and buckling strength compared as Kevlar/epoxy.

As compared to convectional and new design universal joint of carbon fiber reduces the weight near about the 60% and 130% to 140% torque strength increases.

Sr. No.	Material	Theoretical strength	Ansys strength	Practical Strength
1.	Convectional steel	199.6	235	225
2.	Carbon Fiber	293	303	295.2

VII. CONCLUSION

The use of composite material reduces the weight of joint significantly as composite having lower density. Initial torque required to give rotation to the transmission system is large as the weight reduces this surplus torque is utilizes. The reduction in weight gives further advantages in increase in fuel economy of vehicle. In this paper analysis and experimentation being perform on universal joint. In this joint certain modification are made in the existing geometry and analyzes for the identical loading and boundary condition. Universal joint will be analyzing in the ANSYS and result will be compared.

VIII. REFERANCES

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