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Structural and Finite Element Analysis of Steering Yoke of an Automobile

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ABSTRACT

This paper postulates the study of the structural analysis of steering yoke. In a steering system, steering column is one of the main device of an automobile. It is a very important to attain stability and steady movement of vehicle. The core part of steering column is manufactured through various processes such as hot forging, machining and assembly by welding. Power transmission system of vehicle consist several components which sometimes suffer from different stresses (failures) While a generalized case shall be taken up for study while pursuing dissertation work on this topic, the findings are expected to throw light on the causes, location and extent of stresses on the parts in the sub-assembly In this study, the nature and characteristics of stresses acting on the component by using software tools (for simulation/analysis) are carried out.

***Keywords*--** Steering Yoke, Simulation/Analysis, Stress Analysis, Optimization Torsion & Shear

I. INTRODUCTION

The subassembly of steering yoke associated with this dissertation work consists of two forged-steel yokes or forks joined to the two shafts being coupled and situated at right angles to each other. Although, the single component named `Yoke' would be the topic of interest for this case-study.

A spider hinges these two yokes together. Since the arms of the spider are at right angles, there will be four extreme positions during each revolution when the entire angular movement is being taken by only one half of the joint. This means that the spider arm rocks backwards and forwards between these extremes. Friction due to rubbing between the spider and the yoke bores is minimized by incorporating needle-roller bearings between the hardened spider journals and hardened bearing caps pressed into the yoke bores. A universal joint is a positive, mechanical connection between rotating shafts, which are usually not parallel, but intersecting. They are used to transmit motion, power, or both.

The simplest and most common type is called the Universal joint or Hooke joint. It is shown in figure 1.10. It consists of two yokes, one on each shaft, connected by a cross-shaped intermediate member called the spider. The angle between the two shafts is called the operating angle. It Is generally, but not necessarily, constant during operation. Good design practice calls for low operating angles, often less than 25°, depending on the application. Independent of this guideline, mechanical interference in the construct of Universal joints limits the operating angle to a maximum (often about 37½°), depending on its proportions.

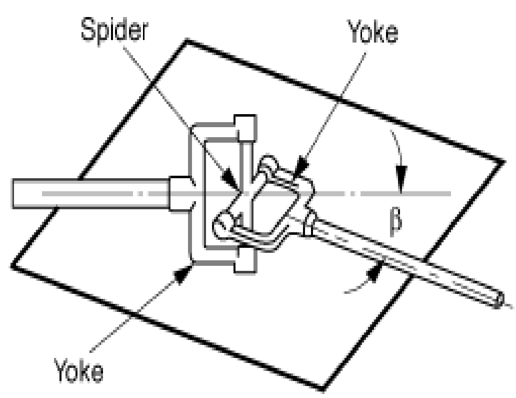

Figure 1: Universal Joint or Hooke Joint

II. OBJECTIVE

To offer Engineering solution to the component named `Yoke' while addressing functionality of the steering column under varying driving conditions encountered during the service life of the component. The component should withstand all the forces acting on it without rupture or failure or undue deformation that might render the component incapable during its service life and/or be a cause of a mishap due to sudden failure during operation

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The purpose of the dissertation is an attempt to evolve an improved design resisting the failure and in turn enhancing the life would be the objective for this dissertation work. The key project objectives for this work as follows:

- Identify and study of the nature and characteristics of stresses acting on the component by using software tools (for simulation/ analysis).
- Evaluate the influence of the loads/ mass/ geometry/ boundary conditions over the nature and extend of stresses.
- Review the existing design and consider improvement for regarding the harmful influences of undue stresses (Torsion or Shear)
- Carry out physical experimentation to validate the model.

III. EXPERIMENTATION

Experimental Method

Upon creating a physical prototype 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. A comparison of the results obtained through physical experimentation and the analytical (using simulation/ software) could offer a basis for validation.

To simulate the working conditions, the force considered to be applied at the spider mounting location as a torsional moment could be about 350 Nm and above (based on the application and the size of the vehicle). However the value takes a minimum and a maximum limit depending on the driving conditions and the auxiliary mechanisms to assist the maneuverability of the vehicle.

Software Method

- Modeling of the Steering Yoke by using 3D Modeling Software CATIA V5 R 17.
- Modeled Geometry is imported in the hyper mesh software through the IGES extension.
- By applying the various boundary conditions like load, moment and various forces acting on the Steering Yoke.
- All the component of steering yoke are meshed by using tetrahedron meshing type.
- By solving the Modeled steering yoke for various conditions of moment and forces.
- Results are obtained and failure analysis has been predicted.
- By modifying geometry at various appropriate conditions and by consider strength and rigidity criteria the optimum solution has been find out.

Analysis of Steering Yoke by using Hyper Works

For modeling of the component, CATIA V5 R17 software is used. Figure No. 6.1 shows the 3D Geometry of Existing component / Steering Yoke Assembly.

With the advancement of finite element analysis (FEA) modeling, model-based design of mechanical structures is replacing the traditional trial-and-error approach. Here the finite element analysis of steering yoke is done in hyper works software.

Procedure for finding out the optimum solution by using Hyper work software.

1. Pre-processing,
2. Processing,
3. Post-processing.

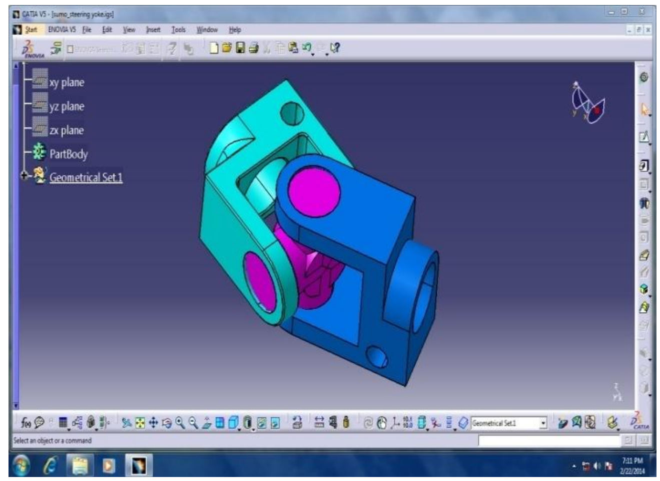

Figure 2: 3D Geometry of Steering Yoke Assembly.

Pre-Processing (Meshing)

After modeling the component and importing to hyper mesh window meshing is carried out. The second order tetrahedral meshing approach is employed for the meshing of the solid region geometry.

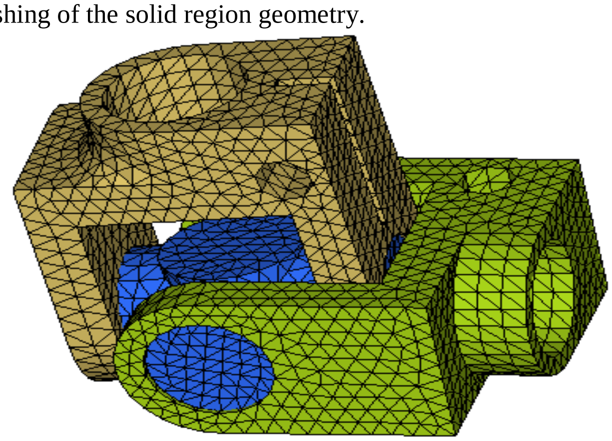

Figure 3: Meshed Assembly of Existing Steering Yoke

Meshing details

Number of elements = 27997
Number of nodes = 28647
Element size = 2.5
Mesh type = Second order Tetrahedron meshing
Processing (or) Solution:

After pre-processing, Loads &boundary conditions are applied as shown in figure 6.3.

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- Boundary conditions is 350 N-m torque is applied at top of steering yoke.
- Constraint (1-6) at lower side.

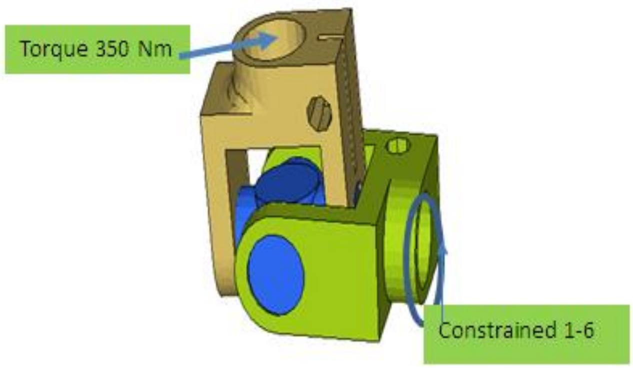

Figure 4: Hyper Work Model With Various Boundary Condition

Torque Applied

The arrow indicates the torque applied i.e. 350 N-m (Abuse load) to the component as shown in figure. Study carried out to observe stress distribution in steering yoke.

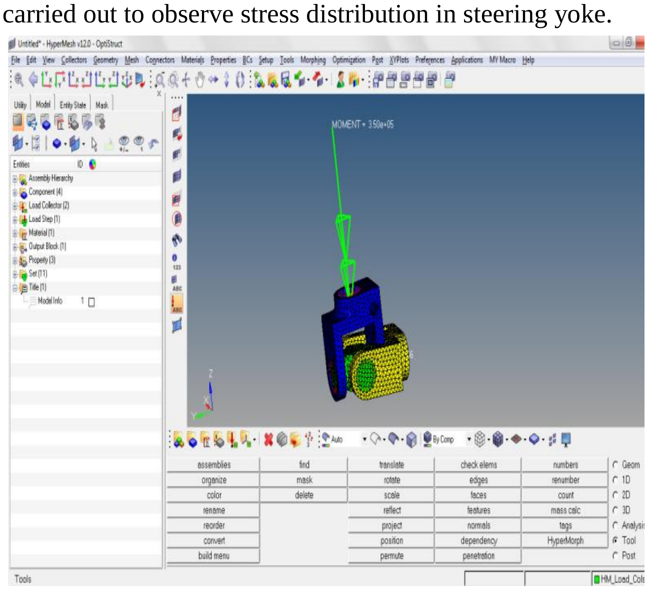

Figure 5: Hyper Work Model With Maximum Torque

Post Processor

In this phase of solution the Steering Yoke Model is used for finding out the values of stress and strain produce during the various loading condition. Following parameters are predicted during post processing phase.

1. Von misses elemental stress
2. Displacement counters.

Firstly the component was designed for that von-misses elemental stress and displacement results are obtained from hyper works

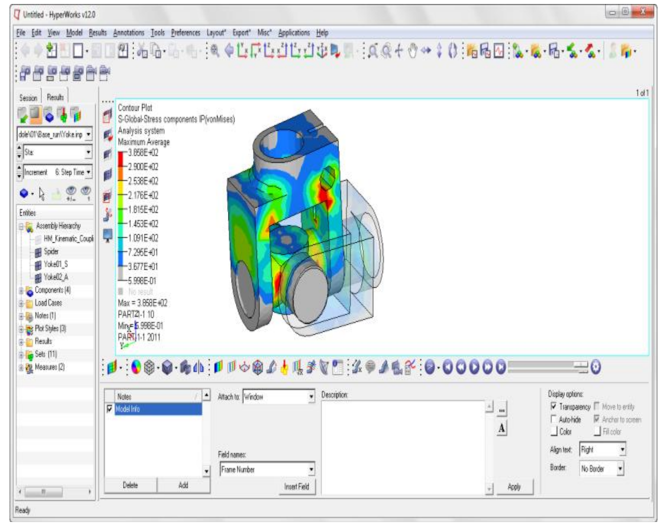

Figure 6: Von mises Element Stress For Existing Yoke

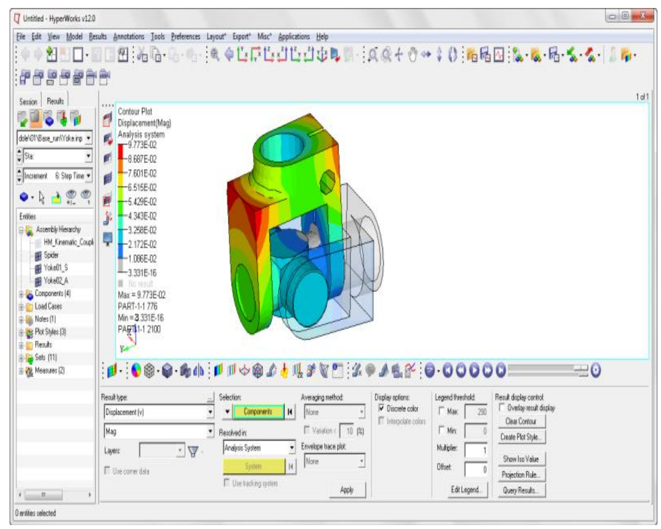

Figure 7: Displacement Counter

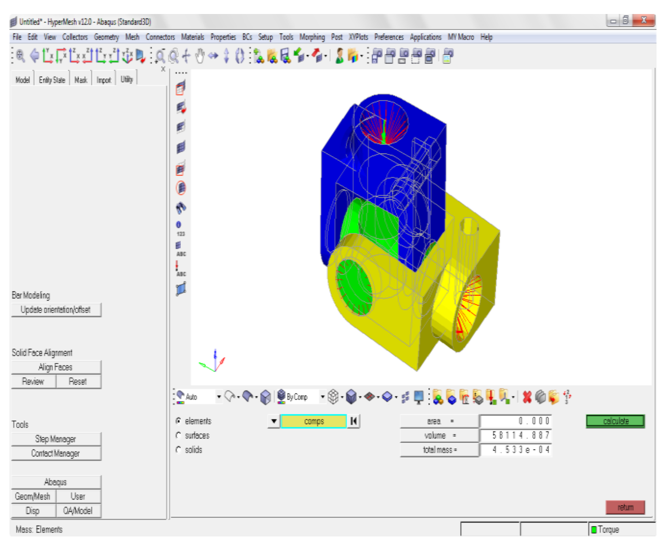

Figure 8: Mass of Component

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Optimization Approach

Optimization is the technique in which the better solution has been find out in order to have the better design by weight, cost and strength and rigidity criteria. By applying various boundary conditions and load on the Steering Yoke better solution has been find out which is to be consider as optimum one. At Maximum loading condition it is observe that Maximum Stresses observed in existing steering yoke is less than the yield stress of the material. Hence the design of steering yoke is safe.

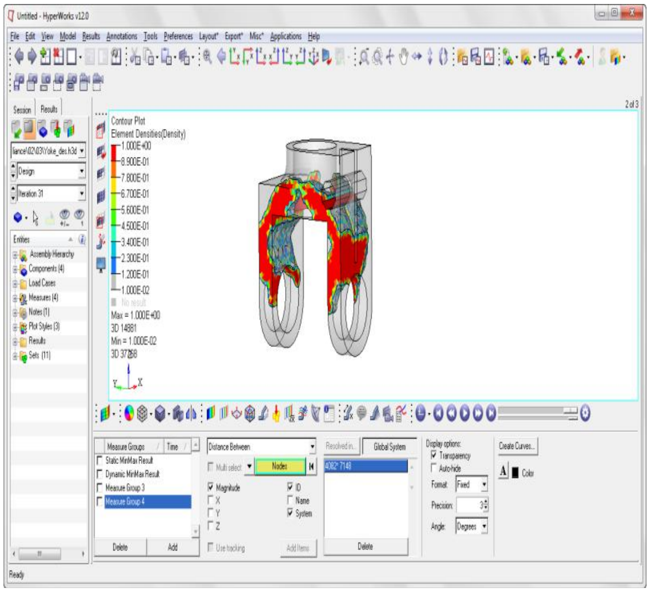

Figure 8: Element Density Distribution

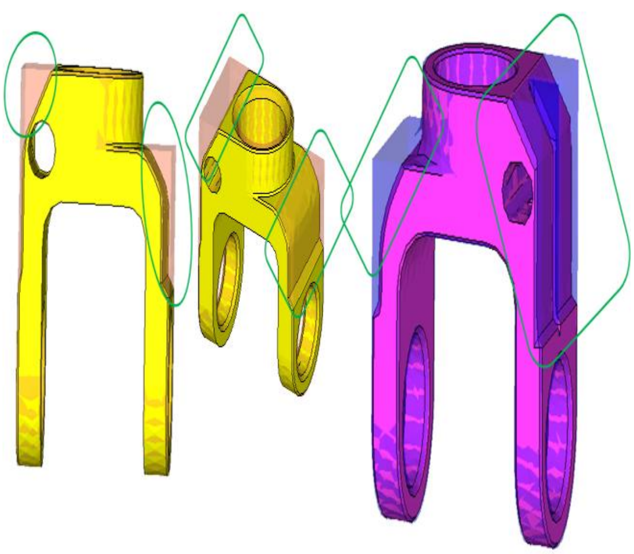

Figure 9: Geometrical Modification in Existing Steering Yoke

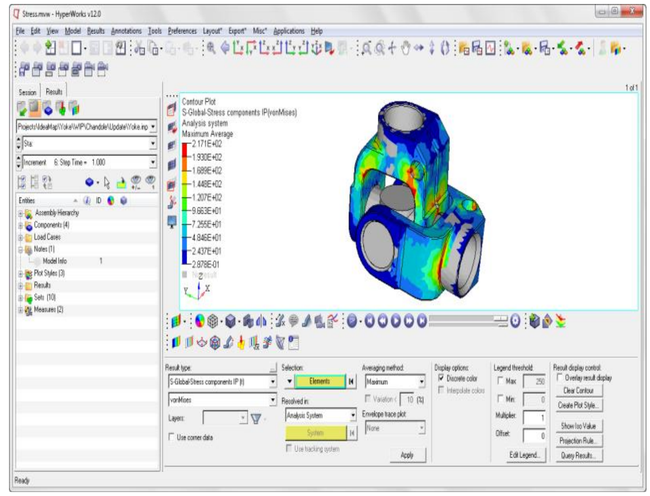

Figure 10: Von mises Element Stress for Modified Yoke

Von mises element stress = 2.171x 10^7 N/m^2.(All the units are in S.I.units system) Therefore, elemental stress = 217MPa (since 1 MPa =10^6 N/m^2).

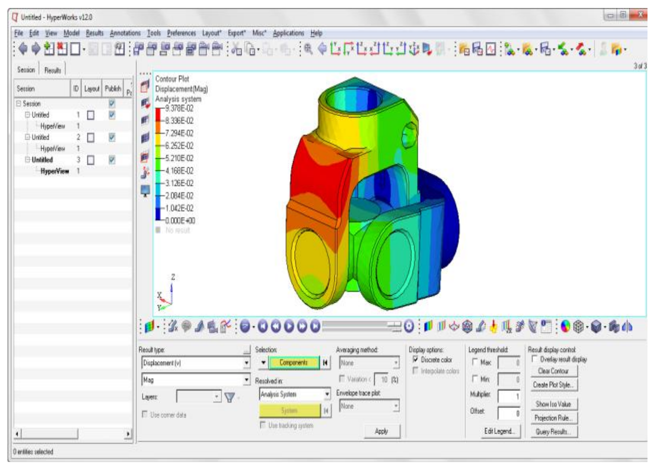

Figure 11: Displacement Counter for Modified Yoke

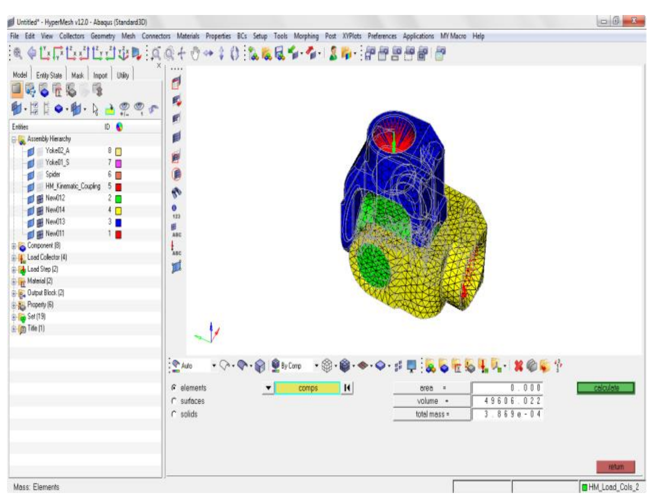

Figure 12: Mass of Component

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Experimental Setup

Torsion Testing Machine

Torsion testing machine capable of determining the shear properties of materials. The shear stress-strain response of materials can be extremely important in the design, analysis and manufacture of a wide variety of products and components which are loaded primarily in shear or torsion. When the applied loadings are primarily shear in nature, the shear modulus of elasticity and shear yield strength must be known in order to apply the usual closed form equations commonly used in engineering design and analysis. These properties are determined from the shear stress-strain diagram which is most commonly measured in torsion test, where a material specimen of solid or hollow round cross section is twisted in a torsion testing machine as the applied torque and angle of twist are recorded simultaneously.

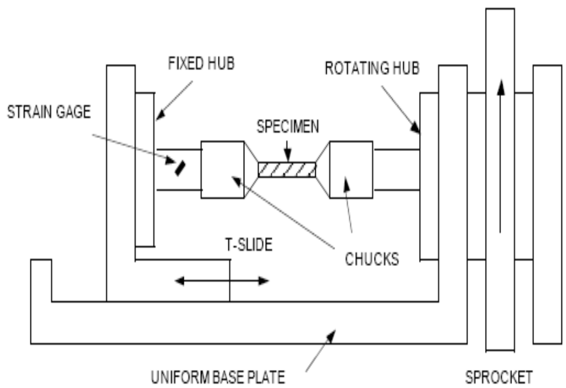

Figure 13: Torsion Testing machine layout

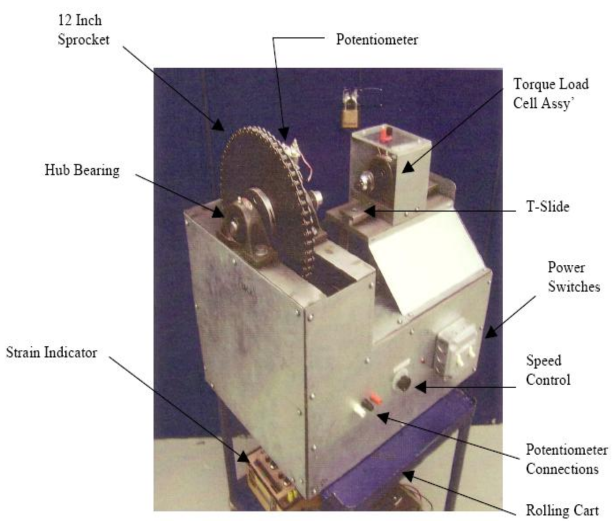

Figure 14: Torsion Testing machine

Torque Measurement

The torque applied to the test component was measured using a strain gauge which was mounted to the non-rotating hub, as shown in figure.

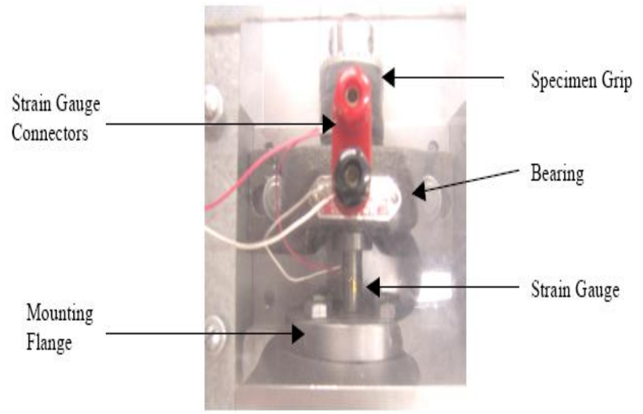

Figure 15: Top View of Torque Load Cell Assembly

Angle of Twist Measurement

The angle of twist was measured using a variable potentiometer which operated off a 5V DC power supply. The potentiometer was connected to a rotating disk which contacted the hub on the driven sprocket, as shown in figure.

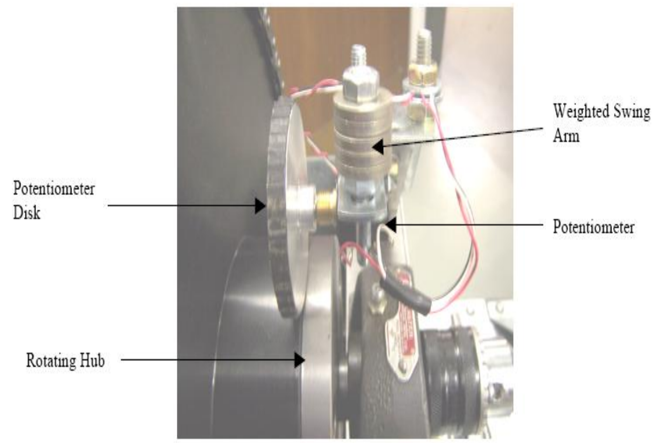

Figure 16: Potentiometer Assembly used for measurement of angle of twist

Experimental Calculations

Maximum principal strain (ε) observed in component = 0.001141 μmm

Elastic modulus (E) = 205 x 〚10〛^(-03) N/mm2

Maximum shear stress (σ) find by using the following equation (3):

E= σ/ε……………………(3)

205 X 〚10〛^(-03) = σ/0.001141

Therefore, σ = 233.90 N/mm2.

Maximum principal stress (σ) in component = 234 N/mm2.

IV. RESULT ANALYSIS

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Parameters	Existing/Original yoke	Modified yoke	Experimental result
Torque (N-m)	350	350	350
Maximum stress (MPa)	386	217	234
Displacement (mm)	$9.773X\ 10^{-2}$	$9.378X\ 10^{-2}$	______
Mass (gram)	450	386	395

Table 1: Result Analysis

V. CONCLUSIONS

In this project work 'design and finite element analysis of steering yoke in automobiles by hyper mesh is carried out. The element stress analysis of steering yoke covers the maximum stress and structure is expected to sustain, without fatigue failure. Hence steering yoke is analyzed for the stress produced under torque/load conditions. The result reveals that

- Steering yoke is analyzed under torque load 350 N-m from steering column.
- Maximum stress observed in the modified steering yoke is 217 MPa (Material Yield stress 250 MPa)
- Maximum Stresses observed in Yoke is well below the yield stress value of the material. NO plasticity observed in the part.
- The mass of modified yoke is reduced by 13.5 % over original component.

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