Evaluating Torsional Stress of Driving Yoke for Steering Column of Light Motor Vehicle

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Abstract - *A universal joint allows driving torque to be carried through two shafts that are at an angle with each other. A simple universal joint carried out two Y shaped yoke, one on driving shaft and other on the driven shaft. The four arms of spider are assembled in needle bearings in the two yokes. The driving shafts and yoke force the spider to rotate. The other two turnnions of the spider then cause the driven toke to rotate. For example a structure may have spatially dependent material properties if different materials are used; the geometry may be irregular in some sense or the boundary condition may be complex. In all these examples no solution functions exist and so solutions can be achieved only by resorting to an approximate numerical method. A widely used numerical method for solving structural problems in both industry and academia is "FINITE ELEMENT METHOD".*

Key Words: CAE, FEA, Cardan joint, HyperMesh, ANSYS, Abaqus, etc.

1. INTRODUCTION

A universal joint allows driving torque to be carried through two shafts that are at an angle with each other. A simple universal joint carried out two Y shaped yoke, one on driving shaft and other on the Driven shaft. The four arms of spider are assembled in needle bearings in the two yokes. The driving shafts and yoke force the spider to rotate. The other two turnnions of the spider then cause the driven toke to rotate.

When the two shafts are at an angle with each other, the needle bearings permit the yokes to swing around on the turnnions with each revolution. 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. The universal joint is used to carry drive from one shaft to another where the two shafts are not perfectly in line and particularly where they can move relative to each other. It is used in propeller shafts at both the transmission output and the differential input ends, in steering swivels on part-time four wheel drive vehicles, in some steering columns.

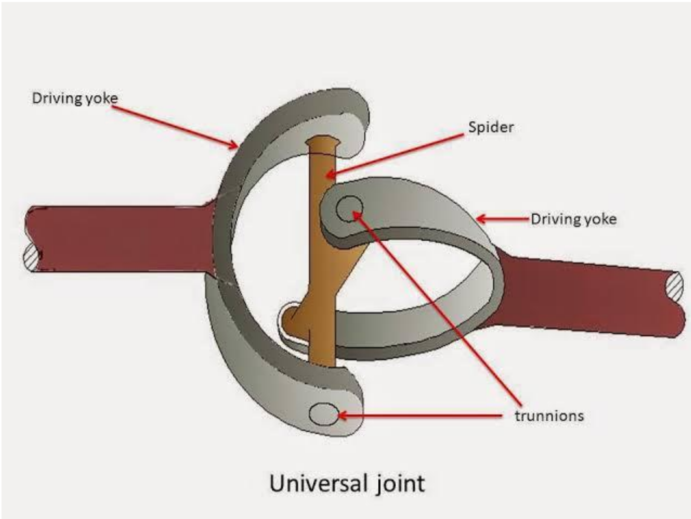

Figure 1.1 Basic structure of universal joint (Cardan joint)

A simple Universal joint does not transmit the motion uniformly when the shafts are operating an angle. Because of this, two universal joints are used in a vehicle, one between the gear box and the propeller shaft and other between the propeller shaft and the differential pinion shaft. Universal joint is a joint in a rigid rod that permits the rod to move up and down while spinning in order to transmit power by changing the angle between the transmission output shaft and the drive shaft. A simple universal joint consists of two Y shaped yokes, one on the driving shaft and other on the Driven shaft and the cross piece called the spider as shown in figure 1.1

2. LITERATURE SURVEY

Mr.P.G.Tathe [1] has developed a methodology, where the 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 Yoke joint, Cardan joint or Hooke joint. 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. Failed Yoke joint is the most common vehicles driveline problem. In this study, failure analysis of a universal joint yoke of an automobile power transmission would be carried out. For the determination of stress conditions at the failed section, stress analyses can also carried out by the finite element method.

M.D.Shende and M.K.Bhavsar [2] have said that, the subassembly of steering yoke associated with this project 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 angle. The most common type of U-joint used in the automobile industry is Hooke or Cardan joint. 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.

S G Solank [3] have adopted, An increased demand for greater performance of universal joint of steering column of passenger car has prompted the development of joints capable of long life at high torque, high angles and high loads. This can be easily achieved by investigating or evaluating the torsion loading and its effect over yoke by FEM. New variations of Universal joint have shown the ability to increase universal joint performance. As Yoke generally subjected to torsional and bending stresses due to wt of components also susceptible fatigue by nature of functioning.

Prof. D.S. Bajaj [4] has advocated, Yoke assembly is one of the most important parts in propeller shaft. In this study, failure analysis of a universal joint yoke of an automobile power transmission system is carried out. First step in this study to find prime mode of failure by using Failure Mode and Effects Analysis technique. Continues variable torque (Torsion) loading & shearing are important mode failure having high risk priority number. Scope of the study is linear static structural stress analysis is carried out by using the following software tools: HyperMesh, ANSYS, Abaqus, or any compatible CAE software in the `Structural' domain.

Maram Venkata and Sunil Reddy [5] has developed, To transmit the driving torque from the engine or gear unit to the final drive by the propeller shaft, we need at least one or two universal joints. In this study, fracture analysis of a universal joint yoke and a drive shaft of an automobile power transmission system are carried out. Spectroscopic analyses, metallographic analyses and hardness measurements are carried out for each part. For the determination of stress conditions at the failed section, stress analysis is also carried out by the finite element method. The common failure types in automobiles and revealed that the failures in the transmission system elements cover 1/4 of all the automobile failures. The failure is analyzed in the ANASYS with FEM.

B Gagan Deep, Lohitesh Jagakumar [6] has defined as the, A car may utilize a longitudinal shaft to convey control from a Motor/transmission to the opposite end of the vehicle before it goes to the wheels. A couple of short drive shafts is usually used to send control from a focal differential, transmission, or transaxle to the wheels. Drive shaft (Propeller shaft) is a mechanical piece of transmission framework which is utilized to exchange the power from motor to the wheel. The exchange and alteration arrangement of vehicles is called as power transmission framework and have diverse productive highlights as per the vehicle's driving write. Most cars today utilize unbending driveshaft to convey control from a transmission to the wheels.

Avinash Chandrashekhar Vasekar [7] has analyze that, In this study, fracture analysis of a universal joint yoke and a drive shaft of an automobile power transmission would be carried out. For the determination of stress conditions at the failed section, stress analyses can also carried out by the finite element method. A finite element stress analysis need to be carried out at the failure region to determine the stress distribution and possible design improvement. An FEA based software like Nastran or ANSYS or any suitable software is utilized for the solving the given problem. The universal joint consists of two forged-steel yokes or forks joined to the two shafts being coupled and situated at right angles to each other. 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.

3. STATEMENT OF THE PROBLEM

The client company is working on the design of a YOKE for steering column of a new car to be introduced in the market. The forces acting on the steering wheel are transmitted to the wheel through a set of components and linkages to generate a mechanical advantage and offer leverage while driving the car. While the car is turned towards the left and to the right, these linkages come into action and transmit the force on the steering wheel through each of these associated components till the wheel could be turned to the desired degrees by person driving the car.

In this process, each component is subjected stresses induced due to torsion, shear, tension or compression. For our case of Yoke, the type of forces influencing its design would largely be attributed to torsion and/or shear. The Yoke assembly consisting two halves of the Yoke is held together with a spider that allows the other end of the steering column to transmit the force at an angle other than the angle for the first part of the steering column attached to the steering wheel.

4. OBJECTIVES

The main aim of the project is to determine the Von misses Stresses and optimization in the existing Steering yoke.

The objective for this dissertation work:-

1) Identify and study using software tools (for simulation/ analysis), the nature and characteristics of stresses acting on the component.
2) Evaluate the influence of the loads/ mass/ geometry/ boundary conditions over the nature and extend of stresses.
General specification of the forged carbon steel:-

- Material used: Forged/Rolled Generic Steel or suitable.
- Material: Forged Carbon Steel C1021 or suitable.
- Heat treatment: Annealed.

5. METHODOLOGY

Analytical Method:- The analytical/ computational approach offers results through simulation/ analyses for the case study predefined for the solver. The technique would deploy any of the following software tools: Patran, Hypermesh, Nastran, Ansys, Abaqus, Radioss or any compatible CAE software in the `Structural' domain.

The CAE software usually has an intuitive graphical user interface with direct access to CAD geometry, advanced tools for meshing and integration with other compatible software for solving. It is optimized for large scale systems, assemblies, dynamics and NVH simulations. Typically, the CAE interface design to handle structural problems as the case study concerned here is adept to linear static analysis with a post-processing.

Steps for the work:-

- Generate the Geometry of Yoke.
- Doing the meshing of that geometry.
- Giving the nature of load and values of loading.
- Solving the meshed model.
- Identify the stressed areas.
- Viewing the results.
- Modify the geometry/mass/boundary conditions.
- Solving the meshed model again in iteration/iterations.
- Comparison of the result.
- Recommendation.

Table -1: Specification for steering yoke

Properties	Value
Material	Forged/Rolled Carbon Steel
Density	7.85 e^{-9} ton/mm^3 or kg/m^3
Poisson's ratio	0.3
Modulus of Elasticity	2.15 e^5 Mpa
Yield stress	305 Mpa

6. FEA FOR EXISTING COMPONENT

The steering yoke is the one of the most important component of the vehicle. A detailed analysis and significant research efforts have been devoted to the investigation of structured analysis of the steering yoke. The effects of the variable parameter such as stress, strain and displacement are computed in the structural analysis under the varying load condition.

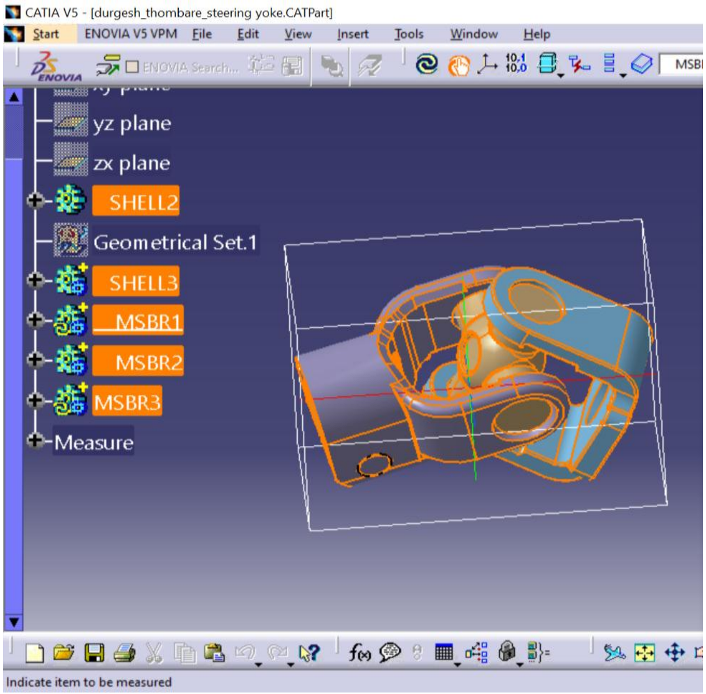

Figure 6.1 CAD Model

In the analysis of existing component, element size of 3mm is taken for meshing. Element size is taken in such a way; every geometry feature should be captured in mesh. More the number of elements accuracy will increase but solution time will also increase so a proper combination between accuracy and solution time is considered while choosing the element size. There are 12,000 no of elements and 23,000 no of nodes observed. Then the yoke is analyzed under torque of 150 Nm from Steering rod. Max stress observed 370 Mpa (yield 305 Mpa). Stresses observed in Yoke are more than yield limit. So there are chances of plasticity or whitening effect at yoke. Part is unsafe under giving boundary conditions.

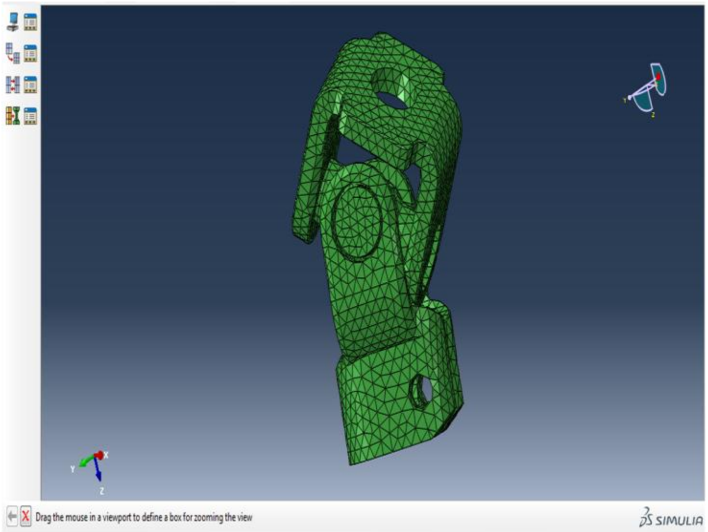

Figure 6.2 Meshing in Hyper mesh

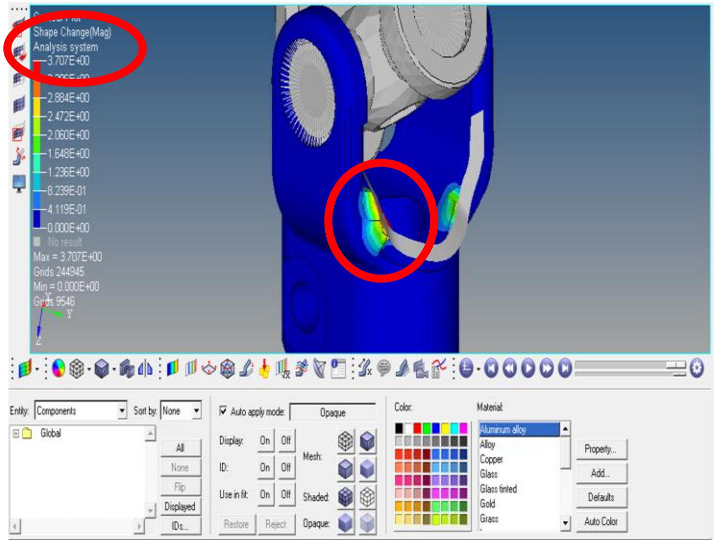

Figure 6.3 Observing hot spot

Topology optimization: Topology optimization is a mathematical approach that optimizes material layout within a given design space, for a given set of loads and boundary conditions such that the resulting layout meets a prescribed set of performance targets. Using topology optimization, engineers can find the best concept design that meets the design requirements. Topology optimization is used at the concept level of the design process to arrive at a conceptual design proposal that is then fine tuned for performance and manufacturability. This replaces time consuming and costly design iteration.

Concluding topology results, small barrier region is defined to reduce stress concentration in affected region. Linear planer constraint defined elements below barrier to freely change shape

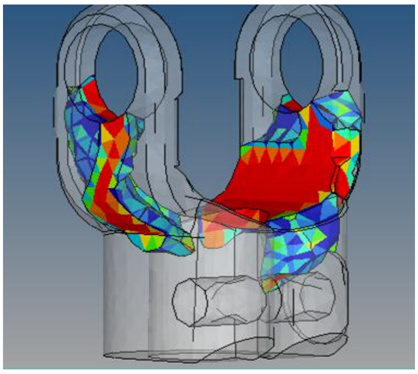

Figure 6.4 Topology optimization

In topology optimization, during the material density distribution, the area which designer has to optimize is come to know. So by considering that much area shape optimization is carried out. Shape optimization: Shape optimization is part of field of optimal control theory. The typical problem is to find the shape which is optimal in that it minimizes a certain cost functional while satisfying given constraints.

To observe stresses with shape variation free size shape optimization is performed. To work further we have to incorporate similar shape modifications to our model. Concluding shape optimization results modification has been done at encircled area. By adopting modification based on free shape optimization stress levels are drop down to 235 Mpa as shown in figure 6.5 comparing to initial design stress 370 Mpa.

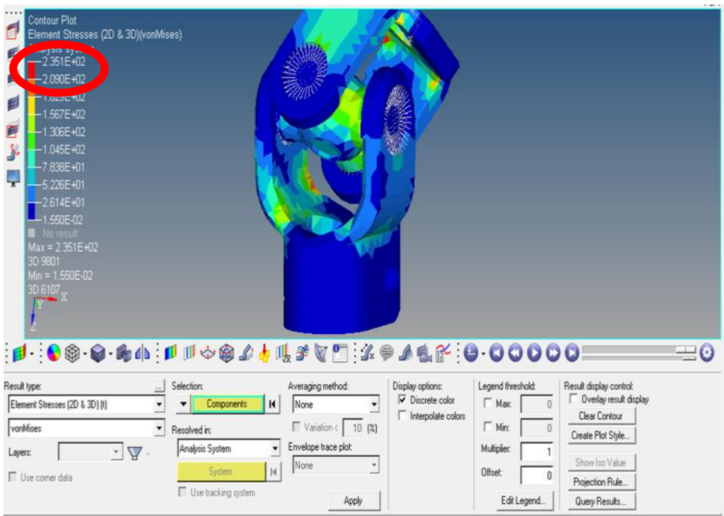

Figure 6.5 Checking stress for modified component

7. RESULT AND CONCLUSION

Initially the yoke is analyzed under torsional loading of 150 Nm at the top side and constraints at the bottom side. With the base design, the initial working stresses of 370 Mpa are observed which are above the yield limit (305 Mpa). After modifications, again the solver is used to run the analysis and the stresses of 235 Mpa are observed.

The iterations are carried out in the analysis phase which yields the suitable values for design parameter.

Yield Stress	305 Mpa
Initial Stress	370 Mpa
Modified/Improved Stress	235 Mpa

As a conclusion following points can be drawn.

1) Part has been found the safe under the given loading condition.
2) The working stresses are less than the yield stress by around 20 % to 25 % which improves the design life of yoke.
3) For modifying the yoke design we also reduce the weight of the given yoke.
4) As the cost of component is also reduced, market demand and profitability will increase which makes the product competitive in the market.

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